16th International Symposium on Advances in Technology Education

Engineering Education After Corona

September 12-15, 2023
Matsue City, Japan

Proceedings

ISATE 2023 Proceedings

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ISATE 2023 Schedule

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(14:00-16:20 Excursion)

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Keynote Session

Dr. Laurence Anthony

Director of the Center for English Language Education in Science and Engineering (CELESE), Waseda University, Japan

Profile

Laurence Anthony is Professor of Applied Linguistics at the Faculty of Science and Engineering, Waseda University, Japan. He has a BSc degree (Mathematical Physics) from the University of Manchester, UK, and MA (TESL/TEFL) and PhD (Applied Linguistics) degrees from the University of Birmingham, UK. He is a founding member of the Center for English Language Education in Science and Engineering (CELESE), which runs discipline-specific language courses for the 10,000 students of the faculty. His main research interests are in corpus linguistics, educational technology, and English for Specific Purposes (ESP) program design and teaching methodologies. He received the National Prize of the Japan Association for English Corpus Studies (JAECS) in 2012 for his work in corpus software tools design, including the creation of AntConc.

Title

Language education in a post-COVID-19 world: Empowering learners through educational technology and language data science

Abstract

In this keynote address, I will begin by describing the current state of STEM language education, stressing the importance of communication as a skill, the four pillars of curriculum and course design, and the roles of instructors and learners. Next, I will discuss how various innovations in educational technology and language data science can significantly enhance opportunities for learner empowerment. These innovations not only allow learners define their learning goals but also enable them to practice language skills beyond traditional classroom confines and assist them in producing target language depending on their needs. I will present these innovations with a view towards the technical writing classroom, but I will also touch on applications that can empower learners when developing their speaking skills, focusing on speed, stress, intonation, and pronunciation. Finally, I will conclude the presentation with a discussion of the potential implications of large language models (LLMs) and other breakthrough technologies on STEM language program goals and administration.

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ISATE2023

Papers

Exploring the Potential of GPT as a Tool for Creating Teaching and Learning Packages

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Abstract

Recent advances in artificial intelligence (AI) have led to the development of chatbots that can generate natural language responses to user queries. One such chatbot is ChatGPT, which is based on the GPT (Generative Pre-trained Transformer) language model. ChatGPT has been used in a variety of applications, including customer service, language translation, and content generation. Researchers have explored the use of ChatGPT to generate Teaching and Learning Packages (TLPs) automatically. ChatGPT can analyze a set of course materials and generate a TLP that is tailored to the needs of students which helps to reduce the time cost and prevent human errors. It can also help to transform an existing question bank in text into an online Moodle quiz at once, therefore, saving a lot of effort adjusting the layout and other settings. ChatGPT may act as a tool to help generating TLPs while must of the ideas are created by educators.

This paper explores the use of ChatGPT, to design and generate TLPs. The paper discusses the benefits and challenges of using AI-generated TLPs, which include notes, worksheets, and online quizzes. The findings are then discussed in terms of the benefits and challenges of using AI-generated TLPs in teaching and learning. The conclusions include a discussion of the limitations of the study and suggestions for future research directions in this area. It is suggested that ChatGPT generated TLPs have the potential to enhance teaching and learning experiences by saving for time cost for creating TLPs. However, there are limitations to the use of AI, such as ensuring that the content generated is accurate and reliable. Moreover, TLPs typically include a collection of resources such as lecture notes, reading materials, videos, and assessments, all related to a specific topic or learning objective, but ChatGPT can only provide text content. The paper concludes by suggesting future research directions in the field of AI-generated TLPs.

Keywords: *ChatGPT, AI chatbot, Teaching and Learning Packages, educational technology*

Introduction and Literature Review

ChatGPT has attracted attention from the academia and many industries. It is a type of language model that is based on the Generative Pre-trained Transformer (GPT) architecture, which was first introduced by Alec Radford, Karthik Narasimhan, Tim Salimans, and Ilya Sutskever (2018) of OpenAI. This architecture was a uni-directional transformer-based language model that used a novel pre-training objective known as "masked language modeling" to learn from large amounts of text data. The authors showed that their model achieved state-of-the-art results on a variety of language understanding tasks, and it paved the way for subsequent research on GPT. After the publication of the paper, there have been many researchers and teams who have contributed to the development of ChatGPT models and their applications. One of the team led by Wang (2019) from the Department of Computer Science and Information Engineering at National Taiwan University proposed the GPT-2 model for building conversational endpoints for chatbots using pre-trained language models. The pre-trained language models have already learned to capture the patterns and structures of natural language, as a starting point for building conversational endpoints. This approach can help to reduce the amount of training data required and improve the quality of chatbot responses. Another paper by Brown (2020) introduced GPT-3 which can perform a wide range of natural language processing tasks with remarkable accuracy, even when given only a few examples of the task at hand. The paper also suggested a wide range of applications, from chatbots and virtual assistants to language translation and content generation. GPT-3 has significantly more parameters than GPT-2, with a maximum of 175 billion parameters compared to GPT-2's 1.5 billion parameters. The larger models can produce more coherent and contextually appropriate responses, but they also require more computational resources and data to train and fine-tune. ChatGPT is based on GPT-3.5 which is an improvement over GPT-3 while ChatGPT Plus utilizes GPT-4. OpenAI stated that GPT-4 is more reliable, creative, and able to handle much more complicated instructions than GPT-3.5. It can take not only text but also images as input. This enable a wide range of application which cannot be done by GPT-3, for instance, answering exam questions which include diagrams.

There are various papers related to utilizing ChatGPT in teaching and learning in different subjects. Liu, Y., Jiang, H. and Zhang, J. (2021) presented a chatbot-based learning system for medical education using GPT-2 to provide personalized learning experiences to medical students. There are numerous studies about using GPT to build language learning systems. Zhao, W. (2020) explored learning system for English writing while Zhang, J. (2020) studied chatbot system for English learning. Wang, X. (2021) also proposed multiple intelligent chatbot systems with GPT-2 and GPT-3 to improve students' language proficiency. It is suggested that such systems could be a useful tool for language learners as these systems may provide personalized learning experiences by giving feedback and suggestions to students on based on their individual strengths and weaknesses. Another chatbot-based system for generating personalized English vocabulary exercises was introduced by Huang, Y. (2021). The ability of GPT to produce natural-sounding sentences and phrases that aid in developing speaking, writing, and comprehension skills has made it a popular tool for language learning. Furthermore, GPT's capacity to process vast amounts of language data can be utilized to develop language learning materials, including customized exercises and assessments that are tailored to the learners' goals and proficiency levels. Consequently, there is significant research on the application of GPT in language learning. In addition to its benefits for language learners, GPT can also find utility in physics education. Huang, Y. (2021) introduced a GPT-3 system to offer personalized learning experiences to students, including answering questions and providing feedback on their understanding of physics concepts.

Several GPT-based chatbots that have been developed and launched for teaching and learning purpose in the education institutes. Duolingo is a language-learning platform that uses GPT-based chatbots to provide interactive conversation practice for its users. The chatbots are designed to simulate real-life conversations and understand and respond to a wide range of user inputs. Aida is another GPT-based chatbot developed by the University of Tartu in Estonia. It is designed to provide personalized guidance and support to students in online learning environments. One of the chatbots, Jill Watson was developed by researchers at Georgia Tech. It was initially used as a teaching assistant in a computer science course, where it was able to answer student questions and provide feedback on assignments. The chatbot was so successful that many students did not realize they were interacting with a machine. Apart from teaching and learning, GPT-based chatbot can also provide mental health support and guidance to students. Woebot was designed to use in educational settings to help students manage stress and anxiety, and to provide resources and referrals to mental health professionals when needed.

There have been numerous discussions in the education sector regarding the use of ChatGPT for creating teaching materials. Several academic papers have suggested that ChatGPT has the potential to generate personalized teaching materials which can enhance the quality of teaching. Wang, X. (2021) and Hao, Y. (2021) have authored several papers on the topic of personalized teaching materials. One of their studies proposed a system that can generate English reading materials based on students' interests and reading levels, which can improve their reading comprehension and motivation. Other than reading materials, ChatGPT can also generate English writing exercises in various formats, including fill-in-the-blank, multiple choice, and short answer according to Liu, Y., Liu, J. and Jiang, H. (2021). Another study by Zhang, Y. and others (2020) also reported that GPT can generate various types of exercises, such as, fill-in-the-blank, matching, and short answer. The same team (2020) suggested that using GPT to automatically generate multiple-choice questions can save time and effort for educators and increase the efficiency of the question generation process. It can also potentially reduce the risk of bias in question creation and increase the accuracy and consistency of the questions. Song, X. (2021) conducted a study on the potential of using GPT-2 for generating questions in educational assessments.

In conclusion, ChatGPT has the potential to revolutionize the creation of teaching materials. Several academic papers suggest that ChatGPT can generate personalized teaching materials, such as English reading and writing exercises, in various formats, including fill-in-the-blank, multiple choice, and short answer. ChatGPT's ability to process large amounts of language data can be leveraged to create exercises and assessments tailored to the learner's proficiency level and learning goals, improving the quality of teaching. The use of ChatGPT for generating teaching materials can reduce the time and effort required by educators, increase efficiency, and provide a more personalized learning experience for students. Further research in this area can bring more advancements to the field of education and improve the quality of teaching and learning. In this work, we explore a cost-effective and convenient method for generating teaching and learning packages (TLPs) comprising of various materials, including notes, tutorials, exercises, and assessments, using ChatGPT.

This paper starts with providing background information and literature review for the ChatGPT and its impact in the education industry, followed by the detailed description of the methodology to produce TLPs and the results. Finally, it ends with conclusions and suggestions for further usage of ChatGPT.

Methodology

To make it easier for teachers from different backgrounds and institutions to use chatbots in their teaching, it is recommended to utilize free ChatGPT chatbots. These chatbots come with sufficient capabilities, making them a practical choice for educators. Additionally, using a free ChatGPT chatbot is a cost-effective and user-friendly option, even for teachers who lack specialized technical skills or resources. There are many free and open-source chatbot platforms that utilize GPT-based models, some of which have pre-built models that can be quickly customized and trained for various educational contexts. Although these tools may not include all the advanced features of expensive chatbot platforms, they can still be highly effective in many educational settings and enhance students' learning experience.

In this study, we employed POE, a free ChatGPT platform developed by Quora. This platform is accessible worldwide and offers an online version, as well as computer and phone apps. Its hardware and software requirements are minimal, making it easily accessible with an internet connection. To access additional features, such as a chatbot based on GPT-4, users can subscribe to a paid plan. While the platform offers multiple chatbots, we focus on utilizing the GPT-3-based chatbot.

There are several functions that ChatGPT can provide to assist in developing TLPs. In this paper we focus on discussing the most useful the functions. Firstly, it can aid in checking grammar and spelling mistakes. Secondly, it can modify the question type of existing questions, for example, converting multiple-choice questions into matching or true/false questions. Chatbots can alter numerical figures in mathematic questions and generate similar questions to provide additional exercises and practice for students. These functions can enhance the variety of the questions and expand the question bank. Thirdly, it can generate notes and tutorials in LaTeX format, eliminating the need for managing document layout, which can be time-consuming. Finally, it can create Moodle quizzes in GIFT format, allowing teachers to upload the file directly to Moodle.

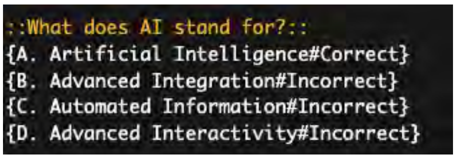
ChatGPT has been trained on a large corpus of text data, consisting of both correct and incorrect language usage examples, to identify grammar and spelling mistakes. During the training process, the model learns to recognize and understand patterns in the text data, enabling it to detect common grammar and spelling errors. When you input text into a ChatGPT-based chatbot that is designed to check for grammar and spelling errors, the chatbot analyzes your text using its pre-trained language model and detects any mistakes it finds. The chatbot then suggests corrections based on the patterns it learned during training. To use ChatGPT to check for errors, simply copy and paste the text into the chatbot conversation. The chatbot will inform you if any errors are found and provide suggestions for correction. The meaning of the text will remain unchanged throughout the process.

One of the functions of ChatGPT is to modify the question type of existing questions, such as converting multiple-choice questions to short questions, changing the options of the multiple-choice questions. This feature can increase the variety of questions and expand the question bank, allowing educators to provide a wider range of assessments to their students. Having a variety of questions on the same topic can greatly benefit students in several ways. It encourages deeper understanding of the material as students are forced to think about the topic from different perspectives. This can help them gain a more holistic understanding of the subject matter. Moreover, presenting information in different formats, such as through matching or true/false questions, can enhance retention. The brain is better able to remember information that is presented in multiple ways, which can help students better retain what they have learned. A variety of questions can help identify any misconceptions that students may have. By asking different types of questions, it becomes easier to identify any areas where students need additional support or clarification. All in all, having a variety of questions on the same topic can enhance the learning experience for students and improve their overall understanding of the subject matter. To modify a question to a different format using ChatGPT, simply input the question into the chatbot's interface and specify the new format to which the question should be converted. The chatbot will analyze the question and convert it to the specified format, providing you with the new version of the question. Another way to increase the variety of questions in the question bank is by changing the order and options of multiple-choice questions or modifying numerical values in existing math exercises. These tasks can be time-consuming if done manually by teachers. However, a chatbot can perform these functions quickly and efficiently. While the depth of the question bank increases, the questions and ideas are still generated by the teacher rather than the bot, ensuring the accuracy and relevance of the knowledge delivered and assessed.

ChatGPT can assist in producing notes, tutorials, and other materials in LaTeX format, taking care of the layout. The generated materials follow standard formats for lecture notes, tutorials, and exercises, ensuring a consistent and clear layout for the entire set of TLPs. Manual adjustment of the layout can be a time-consuming task for teachers, but with ChatGPT, this process is streamlined and automated, saving valuable time and effort. Once the content of the materials has been provided, ChatGPT can generate the material in LaTeX format. The generated code can be copied and pasted into any LaTeX editor. Many LaTeX editors are available for free, including popular ones such as Overleaf, Texmaker, TeXstudio, and more. For this work, we use Overleaf online version due to its accessibility. Teacher can then alter any content afterwards with the LaTeX editor if needed.

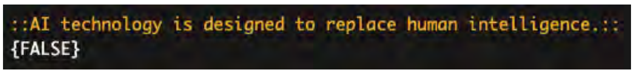
Lastly, the use of ChatGPT to generate Moodle quizzes with existing questions can be a helpful solution. Moodle is a cost-effective and customizable solution for educational institutions. As an open-source platform, Moodle is free to use and can be tailored to meet the unique needs of each institution. This makes Moodle a flexible option for schools, colleges, and universities looking for an affordable and customizable learning management system. The General Import Format Technology (GIFT) file format is utilized for generating and importing quizzes in various learning management systems such as, Moodle and Google Form. It is a plain text file format that allows instructors to create quizzes in a simple and flexible way. The GIFT format supports several types of questions, including multiple choice, true/false, short answer, essay, matching, numerical, fill in the blank, and multiple response. Examples of questions in GIFT format are illustrated in Figure 1 and Figure 2. Manually creating a quiz involves creating a

GIFT file using any plain text editor, such as Notepad or TextEdit. The process involves indicating the question type, adding the question, answer options, correct answers, feedback for each option. Once the GIFT file is created, it can be imported into Moodle or other learning management systems or quiz software to create a test or quiz. It's essential to save the file in plain text format and ensure that it meets GIFT specifications. However, most question banks are in Microsoft Word document format, making it time-consuming to convert them to GIFT format. Another option is to copy and paste each question from the bank, but this can lead to errors such as missing options, duplicated options, or questions. Manually uploading each question to Moodle can be a time-consuming process. With ChatGPT, teachers can upload the existing question bank and automatically generate the quizzes in GIFT format, which can then be directly uploaded to Moodle. This approach can save time and reduce the risk of human error in the quiz creation process.



```
::What does AI stand for?::
{A. Artificial Intelligence#Correct}
{B. Advanced Integration#Incorrect}
{C. Automated Information#Incorrect}
{D. Advanced Interactivity#Incorrect}
```

Figure 1: Example of Multiple-Choice Question in GIFT Format

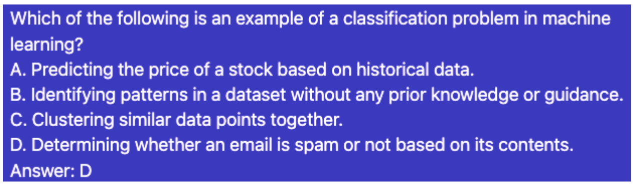


```
::AI technology is designed to replace human intelligence.::
{FALSE}
```

Figure 2: Example of True/False Question in GIFT Format

Results and Discussion

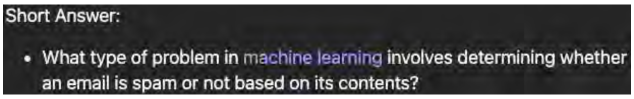
Using ChatGPT to check for grammatical and spelling errors has been successful in our experience. We have observed that the bot is not only capable of identifying grammatical and spelling errors, but also minor punctuation and capitalization mistakes that are often overlooked. ChatGPT has the potential to identify a wide range of other errors in text. For instance, it can detect sentence structure errors, incorrect word usage, and inconsistencies in writing style, such as using different tenses or voices within the same piece of writing. Additionally, ChatGPT can help identify instances of plagiarism by comparing the text to a large database of existing content. Furthermore, it can evaluate the clarity and readability of the text, making suggestions for improvements to enhance the overall quality of the writing. These features are useful in ensuring that the TLPs generated are error-free.



Which of the following is an example of a classification problem in machine learning?
A. Predicting the price of a stock based on historical data.
B. Identifying patterns in a dataset without any prior knowledge or guidance.
C. Clustering similar data points together.
D. Determining whether an email is spam or not based on its contents.
Answer: D

Figure 3: Existing Multiple-Choice Question

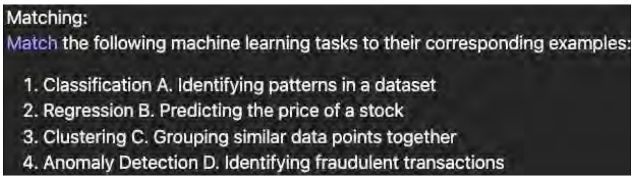
In order to expand the question bank, we provided an existing multiple-choice question to ChatGPT. The model then generated different question types based on the original question. Figure 3 displays the original multiple-choice question. The output results are shown in Figure 4 to Figure 8.



Short Answer:

- What type of problem in machine learning involves determining whether an email is spam or not based on its contents?

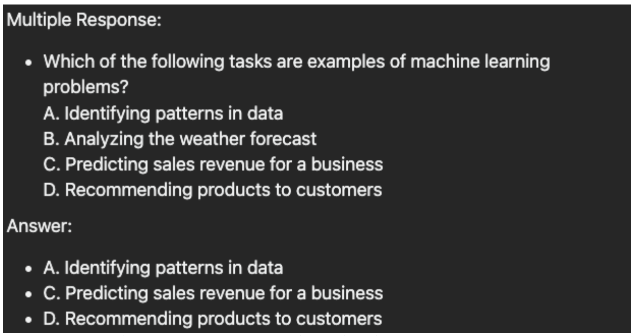
Figure 4: ChatGPT Generated Short Answer Question



Matching:
Match the following machine learning tasks to their corresponding examples:

1. Classification A. Identifying patterns in a dataset
2. Regression B. Predicting the price of a stock
3. Clustering C. Grouping similar data points together
4. Anomaly Detection D. Identifying fraudulent transactions

Figure 5: ChatGPT Generated Matching Question



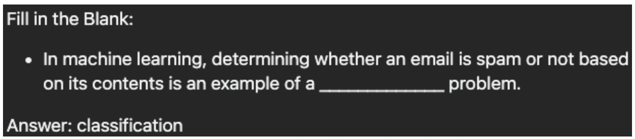
Multiple Response:

- Which of the following tasks are examples of machine learning problems?
  A. Identifying patterns in data
  B. Analyzing the weather forecast
  C. Predicting sales revenue for a business
  D. Recommending products to customers

Answer:

- A. Identifying patterns in data
- C. Predicting sales revenue for a business
- D. Recommending products to customers

Figure 6: ChatGPT Generated Multiple Response Question

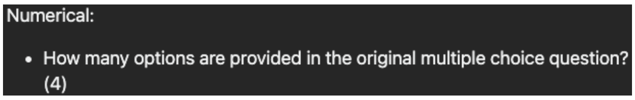


Fill in the Blank:

- In machine learning, determining whether an email is spam or not based on its contents is an example of a ____________ problem.

Answer: classification

Figure 7: ChatGPT Generated Fill in the Blank Question



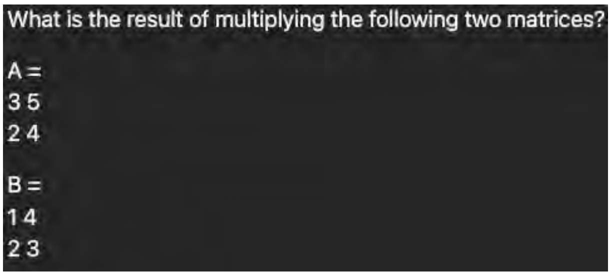
Numerical:

- How many options are provided in the original multiple choice question? (4)

Figure 8: ChatGPT Generated Numerical Question

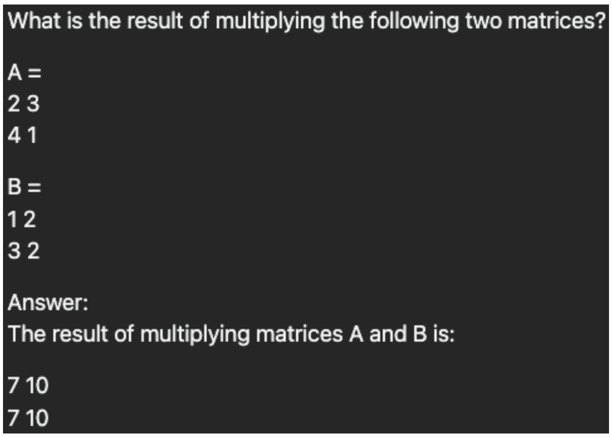
The ability of ChatGPT to generate different types of questions was observed, including true/false, short answer, matching, fill in the blank, and multiple response questions. However, it was unable to generate a meaningful numerical question based on the given multiple-choice question due to the lack of numerical information. It is recommended that teachers exercise caution when using ChatGPT and not rely solely on its output. It is possible for the model to generate useless or meaningless questions.

It is found that ChatGPT can modify the numerical values of a mathematical question with ease. Figure 9 shows the original question as the input while Figure 10 shows the output question along with the solution. Although the tool is highly convenient, it requires clear instructions on how to modify questions. In one case, the bot changed the size of the matrices instead of just altering the numbers, as the instructions were not precise enough. Therefore, it is recommended that teachers provide clear and accurate instructions when using ChatGPT to modify questions.



```
What is the result of multiplying the following two matrices?

A =
3 5
2 4

B =
1 4
2 3
```

Figure 9: Original Mathematics Question

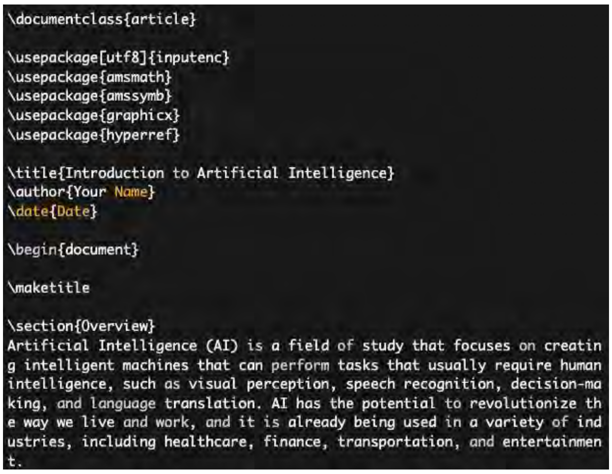


```
What is the result of multiplying the following two matrices?

A =
2 3
4 1

B =
1 2
3 2

Answer:
The result of multiplying matrices A and B is:

7 10
7 10
```

Figure 10: Mathematics Question and Solution Generated by ChatGPT

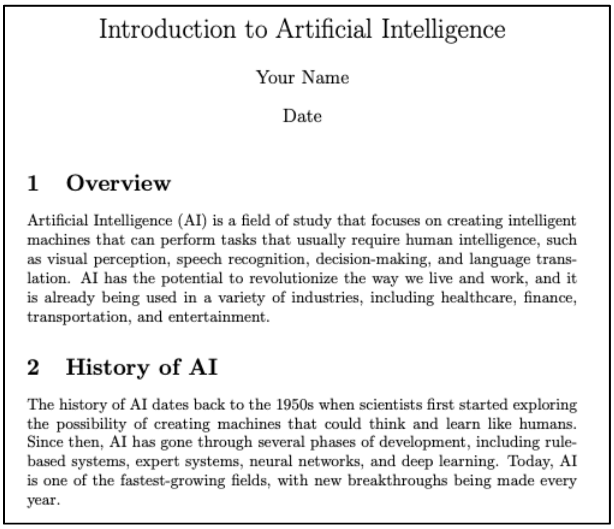
To ensure consistent layouts for the notes and other materials, we use ChatGPT to generate LaTeX code. We input the content that needs to be covered, and the bot takes care of the layout. Figure 11 displays the resulting code produced by the bot, which we then copy into our LaTeX editor. Figure 12 shows the output obtained after compiling the code. This method saves educators a significant amount of time and effort, allowing them to focus on other important aspects of teaching to improve its quality.

When creating a Moodle quiz with ChatGPT, the questions were copied from a Microsoft Word document. However, ChatGPT forgot to mention the question type and did not provide the correct GIFT format initially. ChatGPT generated the right code shown in Figure 13 once we inform it of the mistake. It is recommended to carefully review the output code before use.



```
\documentclass{article}

\usepackage[utf8]{inputenc}
\usepackage{amsmath}
\usepackage{amssymb}
\usepackage{graphicx}
\usepackage{hyperref}

\title{Introduction to Artificial Intelligence}
\author{Your Name}
\date{Date}

\begin{document}

\maketitle

\section{Overview}
Artificial Intelligence (AI) is a field of study that focuses on creatin
g intelligent machines that can perform tasks that usually require human
intelligence, such as visual perception, speech recognition, decision-ma
king, and language translation. AI has the potential to revolutionize th
e way we live and work, and it is already being used in a variety of ind
ustries, including healthcare, finance, transportation, and entertainmen
t.
```

Figure 11: LaTex Code Produced by ChatGPT



Introduction to Artificial Intelligence

Your Name

Date

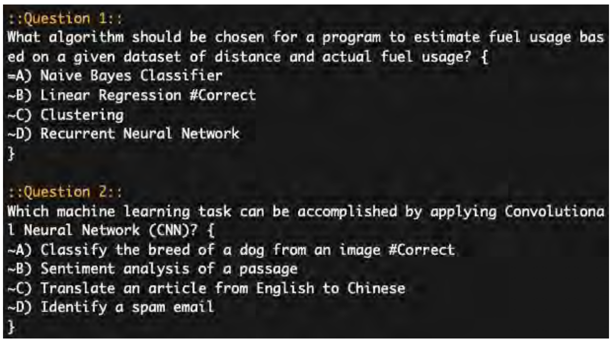
1 Overview

Artificial Intelligence (AI) is a field of study that focuses on creating intelligent machines that can perform tasks that usually require human intelligence, such as visual perception, speech recognition, decision-making, and language translation. AI has the potential to revolutionize the way we live and work, and it is already being used in a variety of industries, including healthcare, finance, transportation, and entertainment.

2 History of AI

The history of AI dates back to the 1950s when scientists first started exploring the possibility of creating machines that could think and learn like humans. Since then, AI has gone through several phases of development, including rule-based systems, expert systems, neural networks, and deep learning. Today, AI is one of the fastest-growing fields, with new breakthroughs being made every year.

Figure 12: Notes Generated by ChatGPT with Latex Code



```
::Question 1::
What algorithm should be chosen for a program to estimate fuel usage bas
ed on a given dataset of distance and actual fuel usage? {
=A) Naive Bayes Classifier
~B) Linear Regression #Correct
~C) Clustering
~D) Recurrent Neural Network
}

::Question 2::
Which machine learning task can be accomplished by applying Convolutiona
l Neural Network (CNN)? {
~A) Classify the breed of a dog from an image #Correct
~B) Sentiment analysis of a passage
~C) Translate an article from English to Chinese
~D) Identify a spam email
}
```

Figure 13: GIFT Code Generated by ChatGPT

Conclusions

ChatGPT has been found to be a useful tool for detecting errors, such as grammatical and spelling errors, as well as sentence structure errors, incorrect word usage, and inconsistencies in writing style. In addition, ChatGPT can generate different types of questions, including true/false, short answer, matching, fill in the blank, and so on with existing questions to expand the question bank. Although ChatGPT can be a valuable tool for generating questions and LaTeX code, it has been known to generate incorrect or meaningless questions. Therefore, caution is advised when using ChatGPT for this purpose. When modifying numerical values of mathematical questions, precise instructions are essential to ensure accuracy. Generating LaTeX code with ChatGPT can save time and help maintain consistent layouts for notes and other materials. For creating a Moodle quiz, ChatGPT can generate GIFT code, which can be a convenient way to save time. However, it is important to note that ChatGPT may not always generate the correct GIFT code, so it is important to review and verify the output. In summary, ChatGPT has the potential to be a valuable tool for educators in performing repetitive and time-consuming tasks, freeing up more time for meaningful teaching and improving the quality of education. However, it is important to note that the accuracy and correctness of the generated materials largely depend on the educators' input and expertise. Therefore, it is crucial to provide accurate and reliable input and instructions to ChatGPT and ensure that the generated output is carefully reviewed and supervised. While ChatGPT can facilitate teaching and learning, it is essential to use it with caution to ensure that the generated materials are accurate, meaningful, and aligned with the desired learning outcomes.

In terms of future development, it has been observed that ChatGPT is currently unable to process images. The ability to do so would be highly beneficial, as students often rely on visual aids in their learning. The capability to generate and comprehend images would also open up opportunities for generating more effective and useful TLPs. Therefore, it is important for future iterations of ChatGPT to incorporate image processing capabilities, which would enhance its overall functionality and usefulness in the field of education.

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A Pilot Study of Using ChatGPT as a Teaching Tool for Software Engineering Education

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Abstract

The aim of this study is to investigate the efficacy of using ChatGPT to support teaching in software engineering education, focusing on its impact on both the efficiency and effectiveness of teaching. The study will employ a mixed-method research design, collecting and analysing both qualitative and quantitative data related to students' academic performance, educators' preparation of teaching and learning material, and students' perceptions of the teaching methods.

The participants of this investigation will consist of higher diploma students in software engineering at the Hong Kong Institute of Vocational Education. These students will be allocated randomly to one of two groups: control group shall be provided with human-created learning content, while the experimental group will receive teaching material and interim feedback generated by ChatGPT.

ChatGPT-generated teaching and learning materials will encompass a variety of resources to support instruction, such as lecture presentations, tutorial notes, assignments and assessments, and marking schemes. These resources will be thoroughly validated and moderated by the lecturer to ensure alignment between the two groups.

Using ChatGPT as a pedagogical tool is expected to amplify the efficiency in teaching software engineering, leading to superior performance by the experimental group over the control group. A supplementary objective of the study is to assess and scrutinise the feasibility of relieving teachers from the burden in preparing instructional materials with the assistance of ChatGPT. The study's results will exemplify the value and usefulness of employing ChatGPT to assist teaching.

This research will contribute to the growing body of knowledge on the use of artificial intelligence in education and has implications for the broader field of teaching and learning. Future research can explore the use of ChatGPT in teaching other subjects and investigate students' perceptions of using ChatGPT as a teaching and learning tool.

Keywords: *ChatGPT, teaching tool, EdTech tool, software engineering education, artificial intelligence-assisted teaching, teaching efficiency, teaching effectiveness*

Introduction

Software engineering is a rapidly evolving field that requires continuous learning and adaptation to new technologies, methodologies, and best practices. Traditional teaching methods and materials in software engineering education face challenges in keeping up with this fast-paced environment, addressing the diverse learning needs of students, and providing timely and personalised feedback (Bourque & Fairley, 2022). These challenges have motivated researchers and educators to explore the use of AI-based tools to enhance teaching and learning experiences in software engineering education (Chiu et al., 2023).

One such AI-based tool is ChatGPT, a state-of-the-art language model developed by OpenAI (Brown et al. , 2020). It has demonstrated remarkable capabilities in generating human-like text, answering questions, providing explanations, and engaging in conversations across various domains (OpenAI, n.d.). The potential applications of ChatGPT in education have started to gain attention, with studies reporting its effectiveness in generating learning materials, providing tutoring, and facilitating collaborative learning activities (Qureshi, 2023). Though the use of ChatGPT in educational institutes is still in argument, there are both challenges and opportunities for education. (Kirk, 2023) It is vital about integrating promising technology in teaching and learning, finding out and tackling down challenges for ensuring successful implementation and positive student outputs. (Passey et al., 2021)

In this pilot study, we investigate the efficiency and effectiveness of using ChatGPT-generated teaching materials for software engineering education in comparison with traditional human-generated content. We aim to answer the following research questions:

1. Can ChatGPT-generated materials be produced more efficiently (in terms of time and resources) than human-generated content?

2. How do students perform and engage with ChatGPT-generated materials compared to traditional human-generated content in a software engineering course?

By addressing these questions, the researchers hope to shed light on the potential benefits and limitations of using ChatGPT as a teaching tool in software engineering education and provide insights for future research and development in this area.

Literature Review

Several studies have investigated the efficiency of computer-generated materials in terms of time and resource requirements. AI in education (AIED) adaptive learning and evaluation applications are widely being used to improve educational effectiveness and efficiency (Chassignol et al., 2018; Kurshan, 2016) together with better understanding of student knowledge acquisition (VanLehn et al., 2007; Beal et al., 2010).

Graesser, Conley and Olney (2012) mentioned an Intelligent Tutoring Systems (ITS) is a computer-based learning tool that makes use of AI to create adaptive educational environments that respond both to the learner’s level and needs, and to the instructional agenda. They also highlighted that ITS often incorporated pedagogical, psychological, and other cognitive learning theories into computational models.

Sarsa, S., Denny, P., Hellas, A., & Leinonen, J. (2022) presented a case study on the automatic generation of programming exercises, including sample solutions and test cases, and code explanations using large language models, demonstrating the capabilities and efficiency of AI tools in content creation. These studies suggest that the majority of the automatically generated content is both novel and sensible. From their analysis, suggesting that there is significant value in massive generative machine learning models as a tool for instructors, there remains a need for some oversight to ensure the quality of the generated content before it is delivered to students.

In the realm of machine learning, Large Language Models (LLMs) that are trained on voluminous textual data, the ChatGPT, is among the notable examples of LLMs. These models have the remarkable capacity to generate code through natural language prompts. Given their potential, there is a global conversation surrounding the ability of LLMs to produce programming assignments and code explanations. This has the potential to revolutionise the teaching practices of instructors.

The potential of Large Language Models (LLMs) in enhancing educators' pedagogy and research has been evaluated by MacNeil, S., Tran, A., Leinonen, J., Denny, P., Kim, J., Hellas, A., Bernstein, S., & Sarsa, S. (2022), demonstrating LLMs capabilities. Their assessment sought to determine the feasibility and manner of integrating LLMs into the learning programming and have the most positive potential impact on computing education.

In a recent study, Qureshi (2023) performed an experiment to evaluate the efficacy of employing ChatGPT in programming problem-solving. The findings of the study demonstrated that the experimental group, which utilised ChatGPT, outperformed the control group by attaining better scores in a shorter amount of time. It is worth noting, however, that despite achieving higher scores, the experimental group was unable to attain perfect scores, as ChatGPT generated code with some inaccuracies or inconsistencies.

Qureshi, B. (2023) has emphasised the necessity of providing training to faculty members in order to equip them with the skills necessary to incorporate AI tools into their teaching methods. Furthermore, Qureshi, B. (2023) advocates for the importance of imparting knowledge on academic integrity to students, with the aim of ensuring their comprehension of the significance of upholding ethical standards in their academic work.

Wang, Z., Lan, A.S., Nie, W., Waters, A.E., Grimaldi, P.J., & Baraniuk, R. (2018) proposed QG-Net, a type of recurrent neural network model that has been specifically crafted for generating quiz questions based on educational content. Their study has demonstrated that the questions generated by QG-Net are notably distinct from the training data. The authors have concluded that the questions created by QG-Net are coherent, pertinent, and closely resemble those created by humans in comparison to existing models. These positive results suggest that QG-Net has the potential to automate and expand the question generation process for educational purposes, thereby complementing the abundant educational content available.

Understanding how students perform and engage with ChatGPT-generated materials is crucial. Cunningham-Nelson, S., Boles, W.W., Trouton, L., & Margerison, E. (2019) shows that chatbots could provide a variety of enhancements for student learning and educator content delivery. Juanan Pereira (2016) mentioned chatbots can be an ideal teacher assistant. P. Smutny and P. Schreiberova (2020) examined educational chatbots in instant messenger to support learning that can provide a basic level of sending personalised messages to recommending learning content. Wollny, Schneider, Di Mitri, Weidlich, Rittberger, and Drachsler (2021) also highlighted that chatbots can foster active participation, provide immediate feedback, and support individualised learning experiences.

Wollny et al. (2021) have pointed to three different pedagogical roles for chatbots in education: a supporting learning role, an assisting role, and a mentoring role. Graham Attwell (2022) conducted a short literature review on using chatbots in education, together with studies of using chatbots for careers guidance, counselling and advice, and concluded that chatbots can be a useful tool in these areas, notably that chatbots are not a replacement for human but should be used as part of a broader strategy.

Holmes, Wayne & Bialik, Maya & Fadel, Charles. (2019) explore the promises and implications of AI in education and highlight the potential of AI tools to support student-centred learning and promote deeper engagement. These studies provide valuable insights into the potential benefits of using computer-generated materials in software engineering education.

ChatGPT-generated materials hold promise in terms of efficiency and student engagement in software engineering education based on the reviewed literature. The studies suggest that ChatGPT can generate materials more efficiently, reducing the time and resources required from educators. Moreover, students may perform better and be more engaged when interacting with ChatGPT-generated materials due to their interactive and personalised nature.

Methodology

This study involved a total of 56 higher diploma students enrolled in a software engineering programme at the Department of Information Technology, Hong Kong Institute of Vocational Education (Sha Tin), following the recommendations for sample size in pilot studies. (Whitehead et al., 2015, Lewis et al., 2021). The students were divided into two groups, each composed of 29 and 27 students respectively. Additionally, a lecturer with over ten years of experience in teaching software engineering related programmes participated in the study to provide guidance, supervision, and evaluation.

Two set of teaching materials were prepared for this study, following the guidelines for creating teaching and learning materials of Vocational Training Council:

Human-generated content: The lecturer prepared a set of traditional instructional materials including lecture notes, workshop exercises and assessments according to the syllabus of the module selected for this study.

ChatGPT-generated materials: The lecturer provided an outline of topics and learning objectives to be covered in the software engineering programme. Using ChatGPT, a set of instruction material, which is similar to Human-generated content, was generated for the same topics and learning objectives.

The content in both sets of materials was reviewed and approved by the module lecturer to ensure accuracy, relevance and comparability.

Procedure

The research context for this project is the learning content on "Micro-services" within the module "Enterprise System Development". This module was selected for this research due to the recent update of its syllabus. Specifically, the addition of "Micro-services" as a new learning content calls for the development of instructional materials to facilitate effective learning. And due to the time constraints, the study was conducted one month, following these steps based on mixed-methods research in education.

Material generation: The lecturer generated the human-generated content, then used ChatGPT to generate the ChatGPT-based materials.

Classroom implementation: Two classes, 56 students in total, were randomly assigned to two groups. Class 2A (29 students) used the human-generated materials, and class 2C (27 students) used the ChatGPT generated content throughout the semester. Before the implementation of the study, both students received human-generated instructional materials.

1. *Data collection:* Quantitative and qualitative data were collected to evaluate the efficiency and effectiveness of the materials. Quantitative data included students' performance on assignments, surveys and completion rates of workshop exercises.. Qualitative data were obtained through interviews and feedback regarding the materials.
2. *Data analysis:* Quantitative data were analysed using descriptive and inferential statistics to compare the performance of students in both groups (Field, 2013). Thematic analysis was employed to analyse the qualitative data, identifying patterns and themes related to students' experiences and perceptions (Braun and Clarke, 2006).

Measures

The following metrics were used to evaluate the efficiency and effectiveness of the ChatGPT-generated materials compared to the human-generated content, based on established evaluation methods in educational research (Fredricks et al., 2004):

1. *Efficiency:* The time and resources required to generate each set of materials were recorded and compared.
2. *Student performance:* Assignment grades, and in-class activity completion rates were compared

between the two groups to assess the effectiveness of the materials.

3. *Student perceptions:* Surveys and interviews were conducted to gather students' feedback on the quality, relevance, and effectiveness of the materials, as well as their overall learning experience (Ryan & Deci, 2000).

These measures allowed us to address the research questions and evaluate the potential of ChatGPT as a teaching tool in software engineering education.

Findings

Test Results and Completion Rate

The study conducted two micro-services workshops with a control group and an experimental group. *Figure 1* presents the completion rates of the workshop exercises. The completion rates for the first workshop were 76.7% for the control group and 70.4% for the experimental group. For the second workshop, the completion rates were 80.0% for the control group and 81.5% for the experimental group. These completion rates suggest that both groups were actively engaged in the workshops, with the experimental group showing slightly higher completion rates than the control group in the second workshop.

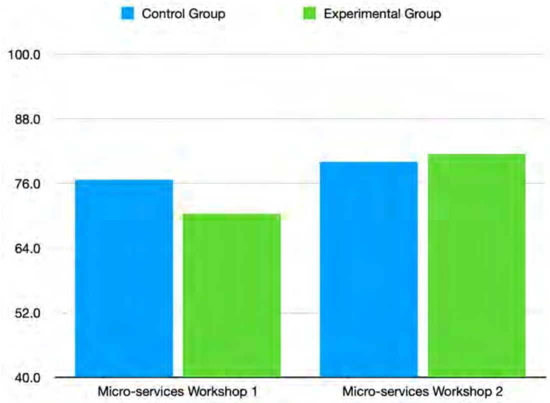


Figure 1. Completion rate of human-generated and ChatGPT generated workshop exercises

In addition, a quiz was conducted to assess the learning outcomes of the micro-services learning content. The average marks for the quiz were 56.7 for the control group and 56.4 for the experimental group, indicating that both groups had similar levels of understanding of the concepts covered in the workshops.

The findings suggest that both the control and experimental groups were equally successful in completing the workshops and had similar levels of understanding of the concepts covered in the quiz.

Student Survey Responses

A total of 46 of 56 research subjects' survey responses were collected and are presented in *Figure 2.*

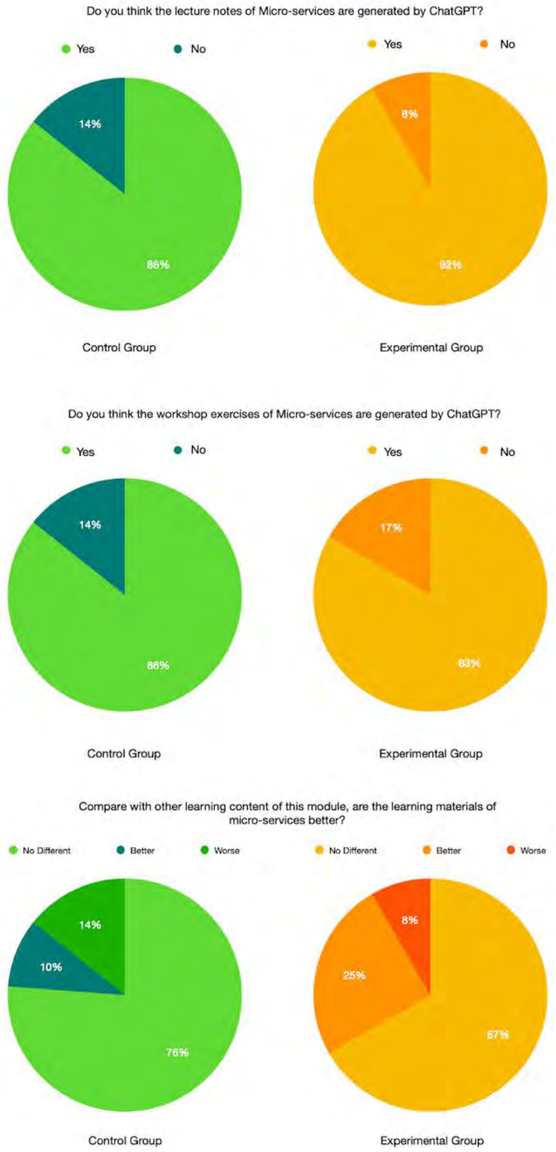


Figure 2. Results of the post-experiment student survey

The survey results provided interesting insights into students' perceptions of the teaching materials. In the first question, 86% of the control group and 92% of the experimental group students believed that their lecture notes were human-generated. This suggests that the majority of both groups perceived the content to be of human origin, regardless of whether it was AI-generated or not.

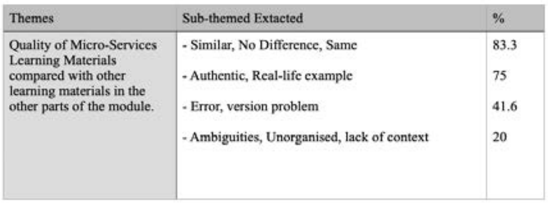
In the second question, 86% of the control group and 83% of the experimental group students believed that their workshop exercises were human-generated. The results are similar to the first question, further emphasising that students in both groups could not clearly differentiate between human-generated and AI-generated content.

The third question compared the learning materials to other content within the module. In the control group, 78% of students felt that the learning materials were no different from other learning materials, and 10% thought they were better. In the experimental group, 67% believed that the learning materials were no different from others, while a higher proportion (25%) thought the learning materials were better. This indicates that a considerable number of students in the experimental group found the AI-generated content to be of higher quality compared to other learning materials in the module.

The survey results demonstrate that students in both the control and experimental groups were largely unable to differentiate between human-generated and AI-generated content, and many of them perceived the AI-generated materials to be of similar or better quality compared to other learning materials in the module.

Students Perception on Instruction Materials

The thematic analysis of the extracted theme focuses on the comparison of ChatGPT-generated learning material in micro-services with human-generated learning materials. The data is derived from a semi-opened interview involving 12 students in an experimental group. The analysis has identified four sub-themes, each with its respective prominence in the data. And the summary of the thematic analysis is presented in *table 1*.



Themes	Sub-themed Extacted	%
Quality of Micro-Services Learning Materials compared with other learning materials in the other parts of the module.	- Similar, No Difference, Same	83.3
	- Authentic, Real-life example	75
	- Error, version problem	41.6
	- Ambiguities, Unorganised, lack of context	20

Table 1. Summary of Thematic Analysis

Similarity (83.3%): The most prominent sub-theme suggests that a significant majority of the students found the ChatGPT-generated learning material to be similar or indistinguishable from human-generated learning materials. This indicates that the quality and content of the ChatGPT-generated material are comparable to those created by humans, at least from the perspective of the students in the experimental group.

Authenticity (75%): The second most prominent sub-theme reveals that the students found the ChatGPT-generated learning material to provide authentic, real-life examples. This suggests that the AI-generated material is relevant and practical, offering value to the learning process by being grounded in real-world situations.

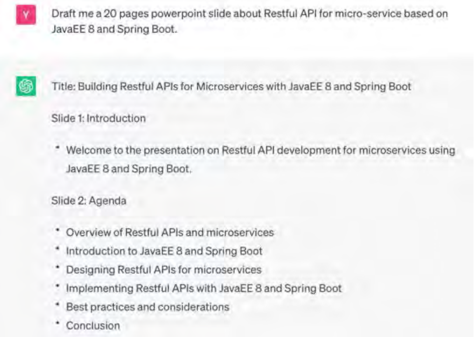
Errors and Version Problems (41.6%): This sub-theme indicates that some students encountered issues with errors or version problems in the ChatGPT-generated learning material. While this does not necessarily imply that the AI-generated material is inferior, it does highlight potential areas for improvement in terms of content accuracy and consistency.

Ambiguities and Lack of Context (20%): The least prominent sub-theme suggests that a minority of the students found the ChatGPT-generated learning material to be ambiguous, unorganised, or lacking context. This may indicate that some of the AI-generated content requires further clarification or additional context to enhance its usefulness and comprehensibility for learners.

Lecturer Preparation Time

The findings indicate that the lecturer dedicated a significant amount of time to prepare for lectures and workshop exercises. For lecture preparation, the lecturer spent around 2-3 hours on tasks such as searching for materials, drafting and finalising the lecture notes. Additionally, the lecturer spent approximately 4-5 hours planning for a theme, program, and validating the code for workshop exercises.

By using ChatGPT, the lecturer followed a different approach. The lecturer spent about 10 minutes entering the prompt and then around 50 minutes validating and transferring the result to PowerPoint. *Figure 3* presents the ChatGPT prompt input by the lecturer to generate the structure for the lecture note. The lecturer then invested 10-20 minutes using ChatGPT to generate workshop exercises with a theme. Finally, the lecturer spent around 2 hours validating the course code and transferring the content to a word document. *Figure 4* presents the prompt used to plan the structure of the workshop. Fig*ure 5* presents the sample code generated by ChatGPT for a given theme about building a student registration system.



Draft me a 20 pages powerpoint slide about Restful API for micro-service based on JavaEE 8 and Spring Boot.

Title: Building Restful APIs for Microservices with JavaEE 8 and Spring Boot

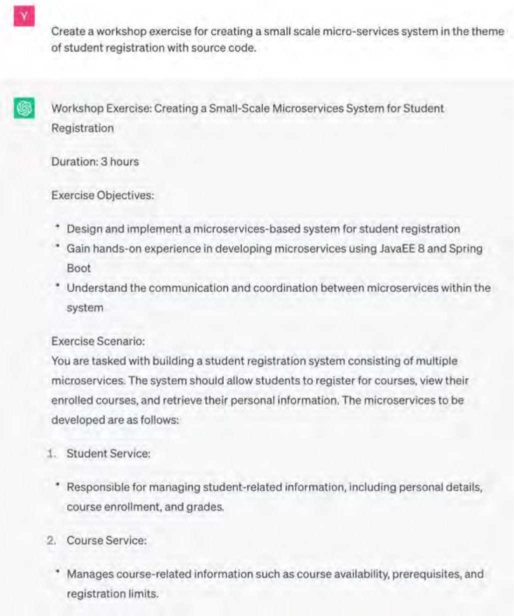
Slide 1: Introduction

- Welcome to the presentation on Restful API development for microservices using JavaEE 8 and Spring Boot.

Slide 2: Agenda

- Overview of Restful APIs and microservices
- Introduction to JavaEE 8 and Spring Boot
- Designing Restful APIs for microservices
- Implementing Restful APIs with JavaEE 8 and Spring Boot
- Best practices and considerations
- Conclusion

Figure 3. Screen Capture of ChatGPT for generating Lecture Note



Y

Create a workshop exercise for creating a small scale micro-services system in the theme of student registration with source code.

Workshop Exercise: Creating a Small-Scale Microservices System for Student Registration

Duration: 3 hours

Exercise Objectives:

- Design and implement a microservices-based system for student registration
- Gain hands-on experience in developing microservices using JavaEE 8 and Spring Boot
- Understand the communication and coordination between microservices within the system

Exercise Scenario:
You are tasked with building a student registration system consisting of multiple microservices. The system should allow students to register for courses, view their enrolled courses, and retrieve their personal information. The microservices to be developed are as follows:

1. Student Service:
   - Responsible for managing student-related information, including personal details, course enrollment, and grades.
2. Course Service:
   - Manages course-related information such as course availability, prerequisites, and registration limits.

Figure 4. Screen Capture of ChatGPT for generating Workshop Exercise

```
@Path("/students")
public class StudentResource {
   @GET
   @Produces(MediaType.APPLICATION_JSON)
   public Response getAllStudents() {
      // Logic to fetch all students from the database
      List<Student> students = // Fetch students from the database


      return Response.ok(students).build();
   }


   @GET
   @Path("/{studentId}")
   @Produces(MediaType.APPLICATION_JSON)
   public Response getStudentById(@PathParam("studentId") String studentId) {
      // Logic to fetch student by ID from the database
      Student student = // Fetch student from the database based on the ID


      if (student != null) {
         return Response.ok(student).build();
      } else {
         return Response.status(Response.Status.NOT_FOUND).build();
      }
   }
   // some source code are trimmed
}
```

Figure 5. Source code extract generated by ChatGPT

It is worth noting that the results obtained from ChatGPT were satisfactory at the level of higher diploma. Additionally, the use of ChatGPT to create learning materials significantly reduced the time needed for preparation. The lecturer spent only a fraction of the time on creating exercises compared to other tasks such as planning and validation.

Quality of ChatGPT-Generated Instructional Materials

Despite the promising results in terms of efficacy and preparation time, ChatGPT-generated workshop exercises were not without issues. Some exercises contained errors, such as incomplete programs or source code that could not be compiled. This highlights the need for further refinement and improvement of ChatGPT-generated materials to ensure their reliability and accuracy in educational settings. For example, ChatGPT may generate deprecated source code from the old version of Java Enterprise Edition.

Discussion

The findings of this study provide valuable insights into the efficacy and efficiency of using ChatGPT-generated teaching materials in the context of computer science education. The results demonstrated that students using AI-generated materials performed similarly to those using human-generated content, indicating that ChatGPT-generated materials can be an effective alternative to traditional teaching resources. Furthermore, students were unable to distinguish between the two types of materials, suggesting that the quality of AI-generated content is comparable to that of human-generated materials.

A significant advantage of using ChatGPT-generated materials was the reduced preparation time for the lecturer. The time saved in preparing lectures and workshop exercises could be allocated to other tasks, such as student support, research, or administrative duties. Additionally, the ease of generating themed workshop exercises using ChatGPT has the potential to enhance the variety and relevance of learning materials, offering students a more engaging and diverse educational experience.

However, the study also revealed some limitations of ChatGPT-generated materials, particularly in the context of workshop exercises. The occasional errors found in the generated source code, such as incomplete programs or code that could not be compiled, highlight the need for further development and refinement of AI-generated content. To ensure the reliability and quality of AI-generated materials, it is crucial to address these issues and implement strategies for detecting and correcting errors before deploying them in an educational setting.

As AI and NLP technologies continue to advance, enhanced versions of ChatGPT might offer improved accuracy and reliability, making it an even more viable option for generating educational materials. Future research should explore the long-term efficacy of using AI-generated content in various educational contexts and investigate potential strategies for addressing the limitations identified in this study. Additionally, the integration of AI-generated materials with other educational technologies, such as learning management systems, adaptive learning platforms, and collaborative learning tools, could further enhance the learning experience for students.

Future Research Directions

To expand on the findings of this study, we suggest several directions for future research. Investigating the long-term impact of using AI-generated teaching materials on student performance, engagement, and retention rates across various educational settings and disciplines could provide valuable insights (Seo et al., 2021). Developing and evaluating methods for automatically detecting and correcting errors in AI-generated content, particularly in the context of code examples and workshop exercises, would help address the limitations identified in this study (Combefis, 2021).

Assessing the effectiveness of integrating AI-generated materials with other educational technologies such as learning management systems, adaptive learning platforms, and collaborative learning tools can provide a more comprehensive understanding of the potential benefits of AI-generated content (Siemens and Baker 2012). Exploring the potential of AI-generated materials to provide personalised and adaptive learning experiences tailored to individual students' needs, learning styles, and progress could enhance the educational experience (Younes, 2021).

Investigating the effectiveness of AI-generated materials when combined with various pedagogical approaches, such as problem-based learning, flipped classrooms, and peer instruction, can help determine the optimal conditions for their implementation (Brame, 2013). Additionally, examining the experiences and perspectives of instructors using AI-generated materials, including their perceptions of quality, utility, and the impact on their teaching practice, can provide further insights into the practical applications of AI-generated content in education (Zawacki-Richter et al., 2019).

By pursuing these research directions, future studies can contribute to a deeper understanding of the potential benefits and challenges associated with using AI-generated teaching materials in education. This knowledge can ultimately help optimise their use and enhance learning outcomes for students.

Conclusions

This study has demonstrated that ChatGPT-generated teaching materials can serve as an effective and efficient alternative to human-generated content in computer science education (OpenAI, n.d.). The findings indicate that students' performance is comparable when using AI-generated materials, and they are unable to distinguish between human-generated and AI-generated content. Furthermore, the reduced preparation time for instructors offers a significant advantage in terms of resource allocation. However, the occasional errors in workshop exercises emphasise the necessity for further refinement of AI-generated materials to ensure their reliability and quality.

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EXAMINING THE EFFECTS OF PRESENTER COACH ON STUDENTS' ORAL PRESENTATION VERBAL DELIVERY

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Abstract

Oral Presentation is a core communication skills competency for polytechnics in Singapore. Proficiency in delivery skills, pitch, volume, and pace, requires personalised feedback. Feedback closes the loop between students' actual and desired performance (De Grez, Valcke & Roosen 2012; Ko, 2019). However, students may not get enough personalised feedback in their practice sessions (Van Ginkel, Gulikers, Biemans, & Mulder, 2015). Recently, Artificial Intelligence (AI) has taken centre stage to enhance presentation effectiveness. Microsoft's Presenter Coach (2019), with an improved version, Speaker Coach (2021), leverages on AI to provide personalised oral presentation feedback. Students click "Rehearse with Coach" and get on-screen guidance on pace, volume, pitch, word stress and filler words, for better delivery (Microsoft, 2019). Personalised feedback is provided through a detailed metrics-based actionable insights report, also highlighting strengths. Research suggests that positive feedback directed at task performance enhances students' self-efficacy (Hattie & Timberly, 2007). A pilot study was conducted in 2020, in Temasek Polytechnic (TP) with 125 part-time students, to measure the effect size of Presenter Coach on students' oral presentation verbal delivery. A quasi-experimental design was used in two formative assessment trial presentations, with comparison. For Trial 1, students presented without exposure to Presenter Coach. Tutors rated students' delivery using standardised rubric. After Trial 1, students were exposed to Presenter Coach via a demonstration and practised asynchronously with Presenter Coach. In Trial 2, tutors assessed students' presentation delivery, using identical rubric. In 2021, the study was replicated with 175 part-time students. Students completed a perception survey on the usefulness of practice with Presenter Coach. In 2022, 392 full-time students completed the same survey for the subject Effective Communication. The results for the October 2020 cohort suggested a huge effect size (Cohen's d of 2.732) and for the April 2021 cohort, there was a very large effect size (Cohen's d of 1.206).

Keywords: oral presentation, delivery, Speaker Coach, AI, self-directed

Introduction

Oral Presentation is ubiquitous in communication courses as an assessment method across the polytechnic curriculum. Well-delivered oral presentations have impact and can motivate and move audiences. They also help in students' preparation for participation in the workplace (Morley, 2001). According to the Singapore Standard Occupational Classification (SSOC), level 4 classification occupations, those often helmed by diploma and degree holders, require a significant level of interpersonal communication skills (SkillsFuture Singapore, 2022), including oral presentation delivery.

However, there are issues relating to oral presentation delivery from students' perspective. One issue is the need for precision in delivery aspects to ensure corrective action by student presenters. Students are often less effective in self-directed practice, necessary for confident oral presentation delivery, because they lack specific knowledge of the verbal or vocal delivery aspects of oral presentation: pace, pitch, volume, use of filler words, and intonation (Tsang, 2020). Students also fear oral presentation because of speaking anxiety (Grieve et al, 2021) and this was intensified during the COVID pandemic when home-based learning was implemented. There was increased anxiety because students had to practise oral presentation delivery without consistent feedback from tutors in a face-to-face mode. According to Hattie (2001), feedback is of one of the most powerful tools for improvement in student performance. Feedback is defined as "information provided by an agent to a learner relating to their skills or understanding as demonstrated on a task or in the completion of a task, usually after instruction" (Hattie & Timperley, 2007).

To address the issues related to the need for specific and timely feedback, the authors decided to use AI to bridge the learning gap and provide students with consistent feedback.

Microsoft's Presenter Coach (called Speaker Coach in 2021) was considered by the authors as a tool to provide real-time insights and metrics to guide students' self-directed practice in oral presentation skills related to verbal delivery. The study, and the results and conclusions, will be described below.

Pedagogy

The pedagogy used is active learning employing AI-assisted enhancement of students' self-directed Oral Presentation practice using Microsoft's Presenter Coach in the classroom. The use of AI has recently been examined by researchers. Chen et al (2023) observed that AI can be leveraged to teach oral presentation skills. This is achieved through personalised feedback to aid students' oral presentation skills. Another area where oral presentation skills can be enhanced is through practice. Hattie (2018) suggests that deliberate practice is said to have an effect size of 0.79 in student achievement. This suggests that sustained, consistent, targetted practice aimed at improving performance is crucial in student attainment. Presenter Coach is available to all TP students both full-time and part-time as part of the Office 365 suite, making practice convenient and the use, scalable. The software requirements are not too exclusive. Presenter Coach uses browsers such as Chrome and Edge. All that is needed is a serviceable microphone and a working camera. The ease of use is also a factor that was considered because students can launch PowerPoint online, go into "Slideshow" mode and click "Rehearse with Coach" to receive specific and thorough feedback.

Presenter Coach also provides a report after each practice with detailed input on aspects of verbal delivery. This report can be saved and reviewed at the students' convenience or shared with the tutor for additional insights. The report acts as a source of formative feedback, a critical aspect of meaningful learning. According to Shute (2008), formative feedback or information given to learners to modify thinking in relation to a task needs to be timely, specific, targetted, nonevaluative and supportive. The gentle nudges in the form of encouraging, friendly reminders and recommendations, for example, to slow down and breathe, if the pace is too fast, are motivating, while being detailed and actionable.

The personalised feedback also helps students improve as does the real-time data, useful for students to adjust their delivery aspects as they practise the presentation. The tool is also available round the clock, so the option to receive detailed feedback is available. In Visible Learning for Teachers, Hattie (2012) contends that students' learning needs to be made visible to teachers. The provision of detailed metrics and the possibility of comparing the reports to track improvements in students' performance with each practice also intensifies learning.

Methodology

To examine the effect size of practice with Presenter Coach, two cohorts of 215 part-time students doing the subject Reports & Oral Presentation over two semesters in October 2020 and April 2021 underwent a study. In October 2020, two diplomas, with a sample size of 92 students underwent the study. In 2021, an additonal diploma took the subject Reports & Oral Presentation, with a sample size of 123. The study had three research questions:

1. What is the effect size of practice with Presenter Coach?
2. What are students' views of practice with Presenter Coach for oral presentation verbal delivery?
3. What aspects of verbal delivery do students think Presenter Coach addresses?

For the study, with two cohorts of part-time students, a quasi-experimental design was employed. Students began their oral presentation module at the start of Term 2, 12 weeks into the semester. A briefing was conducted and an opt-out system was put into effect based on institutional ethics guidelines. In Week 14, Trial 1 was conducted where students verbal delivery was assessed based on a verbal delivery rubric. There was no exposure to Presenter Coach. The formative assessment recorded on Excel sheets was conducted by tutors over MS Teams.

Before the trials, all tutors underwent training to ensure that the inter-rater reliability was consistent. Benchmarking was employed to ensure that there was consistency in marking standards across the tutors. The aspects examined were pace, intonation, volume, and the use of fillers. The concepts related to verbal delivery were also taught to students using examples. A standardised set of PowerPoint slides were used to explain the concepts to ensure consistency in learning the terms or concepts associated with verbal delivery. Presenter Coach was not referred to during this period to prevent sensitisation.

At the end of Trial 1, students were introduced to Presenter Coach in a mass briefing that was given in the form of a recorded online demonstration. The demonstration video could be reviewed by students as required. In Week 15, students practised with Presenter Coach asynchronously. They were required to submit their Presenter Coach reports as evidence of having completed the practice. No practice sessions were held with the tutor.

In Week 16, Trial 2 was held on MS Teams and students practised with Presenter Coach. They were assessed using the same set of rubrics and their assessment was recorded. Their marks were also captured in an Excel sheet.

Results and Discussion

The results of the study indicated that there was a statistically significant difference in the mean test scores of the students in Trial 1, before exposure to the intervention, Presenter Coach, and at Trial 2, after exposure to Presenter Coach. This finding was consistent with both cohorts, the October 2020 cohort, and the April 2021 cohort. Overall, it is found that Presenter Coach does improve students' oral presentation delivery.

In this study, participants' performance was measured using a pre-test and a post-test method. The pre-test scores, denoted as 'm1', were obtained prior to the intervention, while the post-test scores, denoted as 'm2', were collected after the application of the intervention. The pre-test scores (m1) served as a baseline measurement of participants' initial verbal delivery abilities , while the post-test scores (m2) reflected their performance or outcomes after the intervention.

The results of the October 2020 cohort indicated that the mean score for m2 was 9.56 (SD = 0.99), while the mean score for m1 was 12.15 (SD = 1.12). A moderate positive correlation was observed between the two variables ($r = 0.60, p < 0.05$), suggesting that there was a significant relationship between m1 and m2. These findings support the hypothesis that there is a meaningful association between these two variables.

The results of the April 2021cohort showed that the mean score for m2 was 10.13 (SD = 1.30), while the mean score for m1 was 11.33 (SD = 1.09). Additionally, the correlation between the two variables was found to be moderate and positive ($r = 0.66, p < 0.05$), suggesting that there was a significant relationship between m1 and m2. These findings provide support for the hypothesis that there is a meaningful association between these two variables.

The p-value obtained from the paired samples t-test for the Oct 2020 cohort was extremely small, approximately 3.61943E-44, indicating a highly significant difference between the pre-test and post-test results. In the Apr 2021, the p-value obtained from the paired samples t-test was found to be extremely small ($p < 0.001$), specifically 2.78631E-25, indicating a highly significant difference between the pre-test and post-test results.

The results of the Cohen's d, a measure of effect size, were also significant. The effect size or Cohen's d was also calculated. A Cohen's d of 2.732 for the October 2020 study suggested a huge effect size, while a Cohen's d of 1.206 for the April 2021 study suggested a very large effect size.

In Week 17, a perception survey was also conducted using MS Forms. This was administered to all students who praticipated in the studies. The students were asked the following questions using Likert Scale binary questions and multiple-response questions:

1. My confidence level in my oral presentation delivery improved after I practised with Presenter Coach.
2. I benefitted from Presenter Coach practice.
3. Did you prefer to practise with Presenter Coach? (Answer "1" for "Yes" and "2" for "No")
4. How did practice with Speaker Coach help you? You can choose more than one option.
    - helped me reduce fillers ("umm", "er")
    - helped me keep to the pace
    - helped me reduce reading from slides
    - helped me improve my pitch
    - helped me improve in language use
    - helped me check the volume of my voice

To ascertain the extent to which the part-time students, adult-learners with full-time jobs, found Presenter Coach useful for their work, an additional open-ended question was asked to ensure workplace relevance of the AI tool.

An additional question was also asked:

How does training in the use of Presenter Coach in aspects such as pitch, volume, pace, filler words, originality, and language use help in your job?

The perception survey was also extended to full-time students in 2022, with 392 students completing the survey. Students in 2020 (97.3%) and 2021 (94.9%) found Presenter Coach useful. The top three areas of benefit were pace, filler reduction and intonation in 2020 and pace, pitch, and volume in 2021. 87.2% of the 392 full-time students benefitted from Speaker Coach practice. Pace, filler reduction, and pitch were the top three benefits.

Anecdotal responses from tutors also confirmed that the assessment by Presenter Coach of students' verbal delivery is similar to tutors' assessments of students' verbal delivery when the final Oral Presentation assessment was conducted online.

Conclusions

The study will interest those keen on exploring AI-enabled feedback on oral presentation, with data-driven insights for effective delivery.

Practice with Speaker Coach is generally recognised and perceived as a positive source of help for students. Most students saw the benefits of AI in improving their vocal delivery. The method should not be too onerous for staff as Speaker Coach is highly accessible and relatively easy to administer. Speaker Coach also uses data based on highly successful presentations, so the insights generated help students hone their skills. Tutors can use data-driven insights to help students improve their oral presentation delivery. Based on the feedback, tutors can also plan targetted interventions to help students overcome areas on weakness. Additionally, unlike a human tutor, AI cannot be overcome by fatigue so students can practise and ask for feedback at any time.

An added advantage is that the insights are improving. The availability of a large number of YouTube videos and online tutorials on PowerPoint online is an added advantage as this helps with troubleshooting, should technical errors arise.

Additional points of help are pronunciation, although this can sometimes be confusing as Speaker Coach seems to recognise the American variety of English.

However, one of the most difficult aspects to address is intonation and this requires tutor intervention because the tendency to slip into a monotone is high.

Future research could examine the use of Speaker Coach as a new tool in MS Teams, to review and enhance oral presentation ability in meetings. Findings in this research can be extended to a larger study so that the results are more generalisable.

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TEACHING AND LEARNING IN POST-CORONA ERA

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Abstract

The mode of teaching and learning has been evolving in the past decades. New theories and methods kept popping up to facilitate teaching and learning. Worldwide in developed countries, 1960-80 was the era when secondary education was stressed and became comprehensive. From time to time, teachers remodel teaching from vertical traditional mode to dynamic mode. Whereas, students started to receive education not only from the school, but also from the environment such as the media.

Facing the constantly changing teaching and learning environment, it is necessary for both teachers and students to be open-minded. After Corona, people start to move on toward paperless education. Online lessons are conducted; learning videos could be recorded for educational purposes. Some beneficial effects are clear including higher efficiency and affordability for students. On the contrary, drawbacks are observed. Technology issues may hinder the continuity in learning. In addition, students are found to be less focused and some of them may even develop a sense of isolation.

The mode of education in the post-Corona era has been developing rapidly. Some advantages and disadvantages are raised. Not only the need of education should be fulfilled, maintaining the connection between teachers and students remains the most important goal.

Keywords: *Post-Corona era, vertical traditional education, paperless education, online education*

Introduction

The coronavirus disease 2019 (COVID-19) pandemic is caused by a virus namely Severe Acute Respiratory Syndrome Coronaviruses-2 (SARS-CoV-2). This coronavirus infects humans, resulting from various clinical manifestations such as flu-like symptoms or some may experience emergency symptoms including trouble breathing, confusion and persistent chest pain (CDC, 2022). The World Health Organization (WHO) stated in order to prevent COVID-19 infection, the public could get vaccinated, maintain personal hygiene, and distance each other by at least 1 meter (WHO, 2023).

The globe has been experiencing a dramatic change in the mode of education during COVID-19 period. We have been switching from a vertical traditional education mode to paperless education. To maintain social distancing, novel digital methods have been implemented to fulfill education needs (Barnes, 2020). Face-to-face lessons changed to online lessons with virtual reality technology; assessments were submitted through online methods (Garcez *et al*., 2022).

Research Methodology

This study was a cross-sectional analysis on different publications on teaching and learning methods in the post-Corona era. Books, online research journals, and newspaper publications had been reviewed. The author reviewed the publications that include the keywords “education mode after COVID-19”, “teaching mode during COVID-19”, “vertical traditional education”, “online education” and “blended teaching mode”.

Teaching and Learning Approaches

Teaching and learning mode has changed dramatically after COVID-19 outbreak. It is noticed that even before the emergence of COVID-19, online or hybrid teaching and learning became trending as there are numerous advantages compared to traditional face-to-face teaching.

In mode of vertical traditional education, educators choose the learning content and the way to teach students (Ilie & Frăsineanu, 2019). It has been adopted many years ago, thus one of the advantages is that most of the educators are familiar with traditional education. However, the solid and rigid teaching structure may hinder students from developing creativity and the ability of self-learning.

During the COVID-19 pandemic, schools were closed and social distancing measures were adopted. Teaching and learning activities changed from face-to-face mode to online mode. Online lessons were conducted; learning videos were recorded for education purposes. Some beneficial effects are clear including higher efficiency and affordability for students. On the contrary, drawbacks are observed (Harmey & Moss, 2021).

As teachers and students lack direct interactions during school closures and lockdowns, teachers found themselves under tremendous pressure as they need to handle multiple tasks which include online teaching, developing various forms of assessment, and tracking students learning progress (Shimony *et al*., 2022). On the other hand, students were also stressed and found to be less focused. Not a few journal articles and reviews identify the learning loss or disruption during the COVID-19 pandemic (Donnelly & Patrinos, 2021) (Engzell *et al*., 2021) (Kuhfeld *et al*., 2022). In addition to the potential learning disruption, some of the students may even develop a sense of isolation.

Activities to Facilitate the Learning Process

As both educators and students are facing the constantly changing education environment, new guidelines and instructions should be implemented to facilitate the learning process. Some suggested activities are listed on Table 1 and Table 2.

Table 1. Activities to facilitate the teaching process

	Introduction to the online teaching system	*Regular review of teaching progress*	*Counseling*
Teachers	Teachers were used to traditional face-to-face teaching mode. An introduction to the online communication software program is necessary. The introduction should include the procedure of uploading teaching notes, marking assignments and video-making if necessary.	After the implementation of the online teaching scheme, it is recommended to conduct regular reviews to collect teachers' opinions on the software. Teachers should be notified of any system updates beforehand.	Shimony *et al.* (2022) demonstrated the pressure and stress teachers experienced during COVID-19 pandemic. A study conducted by Jakubowski and Sitko-Dominik in 2021 revealed that over 50% of the interviewed teachers had experienced burnout. Counseling is necessary.

Table 2. Activities to facilitate the learning process

	Introduction to the online learning system	*Regular review of learning progress*	*Counseling*
Students	Students should be briefed before attending online classes. They may lose interest in learning when they face difficulties utilizing the software.	Some of the students may have a good kickstart on online learning as they found it flexible. However, students may develop a sense of isolation or a decline in academic results if online lessons last.	In 2021, Holm-Hadulla *et al.* surveyed over 2,000 university students. Over 70% of respondents feel their well-being is disastrously impaired. During and after the COVID-19 pandemic, counseling for students should be done.

Balance Between New Education Technology and Learning

During the COVID-19 pandemic, remote teaching dominated. The role of educators not only includes teaching, but expands to supporting students' online assignments and tasks (Xie *et al.*, 2021) (Nordmann *et al.*, 2020). The beneficial effects of online and new education technology are clear including higher efficiency and affordability for students. On the contrary, technology issues may hinder the continuity of learning.

From time to time, the education sector focuses on different aspects. Since 2019, we stressed the use of online or remote teaching and learning methods. In the post-COVID era, the globe is approaching the new "normal" routine. From the year 2022 and beyond, many schools and institutes emphasized hybrid learning mode, which integrates face-to-face classes and remote online classes in order to achieve the best learning experience (Ratten, 2023).

Conclusions

Teachers and students are adapting to new education modes before and during the COVID-19 pandemic. It should be clear that learning knowledge is not the only goal of education. Face-to-face classes allow students and teachers to develop a deeper connection which facilitates the learning process.

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Demonstrating Engineering Experiments during Webinar Sessions with Turku University of Applied Sciences

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Abstract

In 2021, the National Institute of Technology (KOSEN), Suzuka College, reached a Student Exchange Program Agreement with Turku University of Applied Sciences (TUAS), Finland.
In 2022, based on the agreement, we dispatched two students to TUAS from August to December. In 2023, we will accept one student from TUAS from March to August.

We have already selected 4 students to send to TUAS this summer. Before the agreement, we had a series of webinar sessions with TUAS since 2021. These are not part of a temporary program due to the severe condition of Covid-19, but rather we regard them as continual. It should provide the possibility to interact with students without actual visits. Thus, we aim for the hybrid-international exchange to combine actual visits with virtual ones.

In this paper, we would like to focus on engineering experiments conducted during the webinar sessions. In 2021, as the sessions were based on PBL under the social implementation of technology, each session consisted of a lecture and a follow-up discussion. It was supposed to be difficult to conduct experiments under the strict conditions online, but in the 2022 sessions two experiments were demonstrated; one was the "Tamago Otoshi Contest," the so-called "Egg-Drop Challenge," and the other was the "Sweden Game." The "Tamago Otoshi Contest" includes designing a landing craft that protects an egg passenger when dropped from a high level. The "Sweden game" is a kind of educational gaming aimed at the educational effects on the participants. The game focuses on cost-sharing issues: who will pay the cost and how the total cost will be shared. The webinar sessions are conducted as a part of the "Special Engineering Lecture" with the approval of credits. In addition to the details of the experiments, we would like to present other content incorporated in the "Special Engineering Lecture" toward our hybrid-international exchange.

Keywords: *webinar, hybrid-international exchange, Online Lecture, egg drop challenge, Education gaming, exchange student program agreement*

Introduction

In January 2020, the first case of a new coronavirus infection was confirmed in Japan. Consequently, all international exchange events of Suzuka KOSEN were suspended or canceled. Even small events for international students on campus had to be canceled. In addition, as all regular classes in the spring semester of 2020 had to be shifted online, students were not allowed to learn physics at the college. In the fall semester of 2020, fortunately, we returned to face-to-face classes.

However, since then the overseas school excursion for the second-year students has been postponed, including even domestic factory tours. In addition, all school events such as sports and cultural festivals have also been suspended. However, under the severe conditions of international exchange, our college has tried something new.

One of the benefits resulting from the Covid-19 pandemic is that ICT has been widely used among students and faculty members through online classes. This happened not only in Japan but also in overseas educational institutions. Therefore, since 2021 we have developed an international exchange program using ICT.

Special lectures on engineering connecting overseas online

In 2021, we carried out "Special lectures on engineering connecting to overseas online" with credit instead of oversea internships. This course consisted of three parts: the English presentation-oriented classes, the online intensive lectures by the lecturers at the University of Hannover and two single lectures by US scholars, and the webinar sessions with Turku University of Applied Sciences.

First, in the spring semester, six English presentation-oriented classes were conducted entirely in English by a

native English and English-speaking faculty member. The students created English presentations at the professional level that could be given at international conferences in their respective fields of specialization.
Then, six online intensive lectures were conducted on EMC technology. Dr. Darla Goeres and Dr. Dana M. Barry, respectively, gave a lecture on their majors. Last, in the fall semester, five webinar sessions were held with TUAS. All lecturers lectured on the theme of "Social Implementation."

Lecturers were recommended from both TUAS and Suzuka KOSEN. They were not only faculty members but also a corporate researcher who conducts joint research with Suzuka KOSEN. After the lectures, students were divided into small groups of 6 students (3 Japanese and 3 Finnish) using the Break Up Room function of Teams. Each group discussed the theme given by the lecturer from the perspective of each member's major field. A summary of the discussion was presented to other groups. Participants necessarily communicated with each other in English and deepened their understanding of the social implementation of engineering from cross-cultural and interdisciplinary perspectives. Except for the English presentation-oriented class, these sessions given online were open not only to all faculty and students but also to other KOSENs. In addition, the recorded content is available on demand. Enrolled students are required to submit a report for each lecture to assess their understanding of the content of each lecture.

The webinar sessions were considered an international exchange before the actual visit of Suzuka KOSEN students and the acceptance of TUAS students. The TUAS students who participated in the webinar sessions took a course, "Destination Japan Course," including visiting Japan to study. It was a good opportunity for both sides to get to know each other. This program contributed to the development of a hybrid type of international exchange that combines online exchange and actual visits. It is also expected to establish new mobility for students and to motivate and encourage students to study abroad at educational institutes and to find a new career path after graduation from Suzuka KOSEN. This indicates a new direction for international exchange in the future. Because of these achievements, in November 2021, we concluded a student exchange program agreement with TUAS. Based on the agreement, we sent two students to TUAS in 2022 and will send students there in 2022. Now we accept one student from TUAS in 2023. We would like to focus on the details of the "demonstrating engineering experiments during the webinar sessions" conducted in 2022, in the next section.

Special Lecture for the Project for the Development of Outstanding Global Engineers

As a part of an online exchange program with TUAS, a "Special Lecture for the Project for the Development of Outstanding Global Engineers" was held.
The experiments presented in this paper are supported by the "Sakura Science Program" of JST.

Table 1 Schedule list of special lectures

17 Nov. 2022	" Building a sustainable and comfortable society by Kenji Ikoma Executive Director, AVEX Corporation
2 Dec. 2022	Education Gaming and the Experiment of Sweden Game, by Masashi Kawaguchi
7 Dec. 2022	The Egg Drop Challenge, by Tatsuya Shirai
12 Jan. 2023	The technology industry in Turku University of Applied Sciences, by Tarmo Karhu
19 Jan. 2023	Welcome to Turku University of Applied Sciences! by Hanna Hänninen

On 17 Nov., the lecture was followed by an online discussion between students from TUAS and Suzuka College. The discussion themes were presented by Mr. Ikoma as follows, "How do you foresee the changing times over the next 10 years?" and "What changes do you need to make in yourself to apply what you have learned to your work?". On 2 Dec. and 7 Dec., we held the engineering experiments "Sweden Game" and" Egg Drop Challenge" during webinar sessions. Details will be described later. On 12 Jan. and 19 Jan., TUAS and Suzuka students listened to the lecture by TUAS and answered questions. Afterward, students from both schools exchanged opinions on the presentations of Suzuka students, which were made available on demand in advance.

Demonstrating engineering experiments during webinar sessions

In the 2022 sessions, two experiments were demonstrated; one was the "Tamago Otoshi Contest," the so-called "Egg-Drop Challenge," and the other was the "Sweden Game." The "Tamago Otoshi Contest" includes designing a landing craft that protects an egg passenger when it's dropped from up high. The "Sweden game" is a sort of education gaming aiming at the educational effects on the participants. The game focuses on cost-sharing issues: who will pay the cost and how the total cost will be shared. The webinar sessions are conducted as a part of the "Special Engineering Lecture" with the approval of credits. Details are given in the next chapter.

Tamago Otoshi Contest

The "Tamago Otoshi Contest" includes designing a landing craft that protects an egg passenger when it's dropped from up high. First, a lecture is given on the physical phenomena of this experiment. Then, students discuss how to design a landing craft online, create their craft with only a B4 size paper and glue and experiment with it under almost the same conditions. "Tamago" means "egg" in English. The "Tamago Otoshi" class is conducted under the name of "Egg Drop Challenge" at many schools throughout the world. In general, "Egg Drop Challenge" doesn't set any restrictions on materials. This is an example at the Armidale School.

But this time we would like to set some restrictions on available materials. Participants can only use a designated size of paper, B4, and glue. The glue case is also available for the dropping object. Dr. Koji Ikuta, professor emeritus at the University of Tokyo, spread this “Tamago Otoshi” class widely in Japan. At this time, the experiment was conducted based on Dr. Ikuta’s rules. The rules of the “Tamago Otoshi Contest” are very simple. First, consider how to drop an egg from the 4th story of a building. And actually, drop it.

"How do you avoid breaking a raw egg when dropping it from the 4th story of a building?"

Participants can use any tools to cut the paper, but only the given glue to create the object as shown in Table 2.

Table 2 Given Items

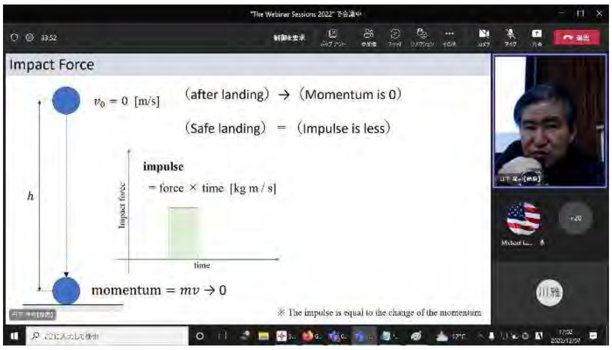
Thick paper（B4 size：257mm x 364mm）
Quick-drying wood glue

Table 3 The participants of raw egg

The same conditions (the same size or shape)
Moderate size and weight
Strong to the pressure on the long axis but weak to that on the short axis
Hard but weak to the impact
Easy to buy (Cheap or abundant)

Figure 1 Eggs are Dropped from the balcony of TUAS

Figure 2 Eggs are dropped from the long stick inside a high-ceiling classroom in Suzuka College



Impact Force

$v_0 = 0$ [m/s]

(after landing) → (Momentum is 0)

(Safe landing) = (Impulse is less)

impulse = force × time [kg m / s]

momentum = $mv \rightarrow 0$

※ The impulse is equal to the change of the momentum

Figure 3 Webinar commentary on mechanics

A raw egg is proper for this experiment. Everyone can participate in the experiment under the same conditions. It is not too small, not too big, not too heavy, and not too light. A raw egg is strong to the pressure on the long axis, but weak to the pressure on the short axis. A raw egg is hard enough to handle but easily broken by the impact. It is easy to judge whether the experiment goes well or not because we can see the broken egg if it fails. In addition, we can buy it easily at the supermarket. This is where we experimented. We put the dropping object on the edge of the long stick and dropped it from the 4th story of the KOSEN building when we experimented with the mechanical engineering students. We covered the ground with a sheet to prevent it from getting dirty from broken eggs. We had to do it under the conditions of a sunny and windless day. But it was very difficult.

Experiment of Tamago Otoshi Contest

On the day of the experiment, each site was connected online. On the Suzuka side, the project was conducted in a classroom with a high ceiling. Inside the classroom, a stick was used to drop eggs covered with buffer material. On the Swedish side, the experiments were conducted in the university or the student’s homes. Eggs were dropped from the balcony or the roof of the home. Although the drop conditions and other factors were different for each, students from both countries were able to work together in an integrated manner on the experiment.

Game and Gaming

In recent years, gaming has gradually been recognized by many people as a new and promising tool to deal with complex problems in which human decisions have far-reaching effects on others. It has been used for various purposes such as education, training, decision-making, entertainment, etc. Along with the appearance of various types of games, continuous effort has been put forth to make existing games more exciting. In this experiment, we carried out the Sweden game and described its educational effect. The Sweden game is one kind of “Education Gaming”. Education Gaming attempts to educate and train all participants. For example, it assumes that students don’t have much interest in economics. After playing the game for a few hours, the students noticed their lack of basic knowledge of economics, and they felt the need to learn economics more strongly. The result is that this game has a very significant educational benefit.

The management game is a kind of Education Gaming that focuses on training. It is made for people working in a middle-class stage of companies. When a person is promoted to a position that has a direct impact on the management of a company, there is the possibility of a big “Risk”. This is because when a person who lacks experience is entrusted with important business, he or she may not know the appropriate action. In such a situation, by playing a game that simulates the management of the company again and again, the person will be able to master "How to manage the company" without entailing a greater risk.

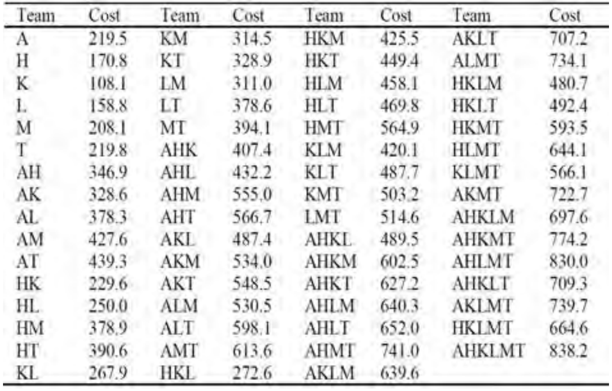
Sweden game and cost-sharing issue

” Sweden game” is a sort of education gaming aiming at the educational effects on the participants. The game focuses on cost-sharing issues: who will pay the cost and how the total cost will be shared. Six regions in the southern area of Sweden are planning to construct pipelines to cooperatively get water resources. Every area wants to minimize its financial expense for pipeline construction as much as possible. Under such a condition, students find the best solution by gaming, discussing, and using shared files online.

Figure 4 Six regions of the southeast area of Sweden, planning pipeline construction.

Figure 4 shows the six regions, A, H, K, L, M, and T in the southern area of Sweden. These six regions are planning to construct pipelines to cooperatively get water resources. The kinds of cooperation, A, H, K, L, M, and T are 2^6-1=63. We show the cost of pipeline construction in Table 4. We show the population of each region and the quantity of spending on water in Table 5. Of course, every area wants to minimize its financial expense for pipeline construction as much as possible. Under such a situation, what is the final solving conclusion? One method is the proportional distribution of an amount of demand. Another method is the proportional distribution by population. Generally, these approaches are good determination methods. In this situation, it is necessary to construct all regions of the pipeline from the whole region's viewpoint.

Table 4 The cost of pipeline construction. (Unit: 100,000 crones)

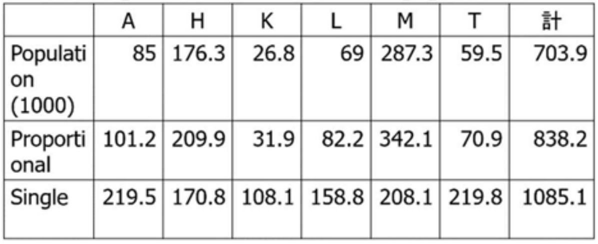


Team	Cost	Team	Cost	Team	Cost	Team	Cost
A	219.5	KM	314.5	HKM	425.5	AKLT	707.2
H	170.8	KT	328.9	HKT	449.4	ALMT	734.1
K	108.1	LM	311.0	HLM	458.1	HKLM	480.7
L	158.8	LT	378.6	HLT	469.8	HKLT	492.4
M	208.1	MT	394.1	HMT	564.9	HKMT	593.5
T	219.8	AHK	407.4	KLM	420.1	HLMT	644.1
AH	346.9	AHL	432.2	KLT	487.7	KLMT	566.1
AK	328.6	AHM	555.0	KMT	503.2	AKMT	722.7
AL	378.3	AHT	566.7	LMT	514.6	AHKLM	697.6
AM	427.6	AKL	487.4	AHKL	489.5	AHKMT	774.2
AT	439.3	AKM	534.0	AHKM	602.5	AHLMT	830.0
HK	229.6	AKT	548.5	AHKT	627.2	AHKLT	709.3
HL	250.0	ALM	530.5	AHLM	640.3	AKLMT	739.7
HM	378.9	ALT	598.1	AHLT	652.0	HKLMT	664.6
HT	390.6	AMT	613.6	AHMT	741.0	AHKLMT	838.2
KL	267.9	HKL	272.6	AKLM	639.6		

Table 5 Population and the quantity of spending water in each region.

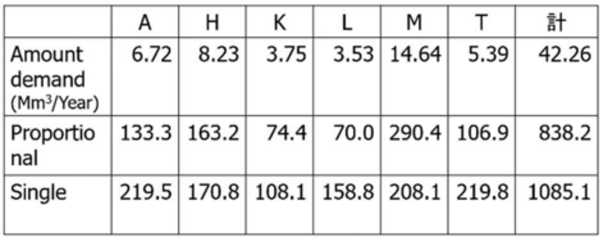
	A	H	K	L	M	T
Population (1000)	85.0	176.3	26.8	69.0	287.3	59.5
Amount demand (Mm^3/Year)	6.72	8.23	3.75	3.53	14.64	5.39

Table 6 Proportional distribution of a population



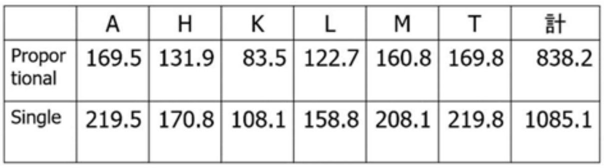
	A	H	K	L	M	T	計
Population (1000)	85	176.3	26.8	69	287.3	59.5	703.9
Proportional	101.2	209.9	31.9	82.2	342.1	70.9	838.2
Single	219.5	170.8	108.1	158.8	208.1	219.8	1085.1

Table 7 Proportional distribution of the amount of water demand



	A	H	K	L	M	T	計
Amount demand (Mm^3/Year)	6.72	8.23	3.75	3.53	14.64	5.39	42.26
Proportional	133.3	163.2	74.4	70.0	290.4	106.9	838.2
Single	219.5	170.8	108.1	158.8	208.1	219.8	1085.1

Table 8 Proportional distribution by the single construction cost



	A	H	K	L	M	T	計
Proportional	169.5	131.9	83.5	122.7	160.8	169.8	838.2
Single	219.5	170.8	108.1	158.8	208.1	219.8	1085.1

However, as shown in Tables 6 and 7, these are not necessarily proportional to the construction expense. Table 6 shows the proportional distribution of a population. In this situation, regions H and M have complained. Because their shoulder costs are 209.9 and 342.1 respectively, but single construction costs are only 170.8 and 208.1 respectively. For regions H and M, it is better to withdraw from the partnership. Table 7 shows the proportional distribution of the amount of water demand. In this case, region M has complained. Because its shoulder cost is 290.4, but the single construction cost is only 208.1. For Region M, it is better to withdraw from the partnership. Table 8 shows the proportional distribution by single construction cost. At first glance, this method of determining the shoulder cost seems to be good.

In this case, the subtotal cost of H, K, and L is 338.1. Because 131.9+83.5+122.7=338.1. However, the cost when HKL is joined up is 272.6, as in Table 4 and the surplus is 338.1-272.6=65.5. Advantageous agreement with only three districts, H, K, and L. These three regions are better to withdraw from the partnership. And A, M, and T have to pay more shoulder costs. This situation is also not a perfect condition. When such difficulty arises, the method of dividing equally is often used. Table 9 shows the assessed contribution according to the Shapley value, Nucleolus, and SCRB. No matter which method is used to determine dues, each region will still be unfairly burdened. For example, region A would favor the SCRB, which is less shoulder cost, while Region H would favor Shapley's method. One useful solution to this problem is gaming.

Table 9 The answer of the following methods.

	A	H	K	L	M	T
Shapley value	200.1	107.1	66.1	103.7	169.4	191.8
Nucleolus	203.5	120.6	50.0	86.1	186.0	192.1
SCRB	195.4	132.8	56.2	109.0	166.6	178.2

Figure 5 Explain to the students about Sweden's game

The experiment of Sweden's game

Each team wants to decrease the amount of their contribution as much as possible. However, if one team tries to save on the shoulder cost, other teams may not join them. When each team cooperates with the others a surplus as large as possible can be attained. However, the best condition is that 6 teams, "AHKLMT" construct a tie-up and the amount of the maximum surplus is just zero. Furthermore, in the situation where the maximum surplus is just zero for the six teams "AHKLMT" due to cooperation, each team must save the suitable shoulder cost.

Before starting the game, we explained to the students in advance the pipeline construction cost of all combinations as shown in Fig. 5. One group has 6-person, A, H, K, L, M, and T. The six members of one group were composed of a mix of both countries. The goal was to achieve an optimal solution through collaborative work by gaming. An Excel-shared file was prepared and the contributions of each district were entered from the group whose contributions were determined. The maximum surplus value was calculated, and the combination of teams was shown when the maximum surplus value was reached. These were calculated by Microsoft Excel and shown to the students by projector as shown in Fig. 6. Although an optimal solution was not obtained, participating students were able to think about the cost-sharing problem while having fun as shown in Table 10. For reference, Table 11 shows good solutions obtained in past gaming classes.

Figure 6 Explain the gaming result using a shared file

Table 10 Gaming results on 2 Dec. 2022

A	H	K	L	M	T	Maximum	Combination
151.1	175	92.2	87.8	207.5	124.7	82.4	HKL
161.6	140	75	120	180	161.6	62.4	HKL
149.8	179.7	90.9	86.5	208.1	123.4	84.4	HKLM
170	150	80	108.2	160	170	65.6	HKL

Table 11 Example of a good answer, each shoulder cost, the combination is "AHKLMT" and maximum surplus is "0" in the past gaming process

A	H	K	L	M	T	Maximum	Combination
184.8	126	55.8	90	199.8	181.8	0	AHKLMT
200.2	119.9	52.9	99.7	172.2	193.3	0	AHKLMT
200	123.3	52.1	90	165	207.8	0	AHKLMT
196.7	109.3	64.8	98.4	178.4	190.6	0	AHKLMT
192.3	107.8	60	84	197	197.1	0	AHKLMT

Conclusions

Due to the pandemic of Covid-19, online exchange programs are getting more and more active. However, no matter how hard we try, there remain some restrictions to online lectures and activities, compared with face-to-face programs. Since 2021, Suzuka KOSEN has held not only lectures but also PBL-style webinar sessions, thanks to the exchange student program agreement with Turku University of Applied Sciences. In the following year, as we mentioned above, the engineering experiments were conducted online. It was a great achievement for both students to participate in the experiment together and share the results online.

Face-to-face exchange programs should be the best, but online PBL classes and experiments also contribute to the promotion of further internationalizing the programs. In the future, we are considering organically combining actual dispatch-acceptance programs and various online exchange programs. The challenge is to further improve the international exchange programs.

Acknowledgments

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Evaluation of International Exchange Activities Focusing on Global Citizenship at Toyota KOSEN

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Abstract

In this research, we report on international exchange activities conducted in 2022 as part of the Global Engineering Development Project "Developing Students' Global Mindset through the 'Use' of English. Through these activities, the results of a questionnaire (Knowledge/Understanding, Skills, Attitudes/Values) based on global citizenship were reported and discussed. During the Corona Disaster, an online video contest connected Japan and other countries as an international exchange activity. Our students and students from overseas paired up and proposed a solution to the issue by creating a video. We also held the second TEDx Toyota KOSEN, inviting six groups of seven speakers from Japan and other countries. The theme of this TEDx was to propose ideas related to the SDGs. The students were involved in the planning, preparing, and implementing the event for over four months. As an international exchange activity after the Corona disaster, 19 students from KMUTT, Thailand's KOSEN, were accepted. The students participated in the event by leading class tours and introducing Japanese culture. Sixty students who participated in these activities were asked to complete a assessment about their international-related skills and awareness. The assessment results before and after the international exchange activities showed that the scores were significantly higher after the international exchange activities, confirming that our activities contributed to improving global citizenship. It was also confirmed that our activities improved "Knowledge and Understanding" and "Attitude, Attitude, and Values." Furthermore, when the pre- and post-activity values were compared by whether the students had studied abroad for a long period, those who had studied abroad for a long period showed a slight improvement in their assessment values. In contrast, those who had not studied abroad for a long period showed a significant improvement. These results indicate that international exchange activities on campus foster global citizenship in students who have yet to study abroad and are effective enough to complement the long-term study abroad experience.

Keywords: *International Exchange Activities, Global Citizenship, Assessment, Attitude, Knowledge, Skills*

Introduction

KOSEN is an institution of higher education that provide engineering education for students between the ages of 15 and 20. According to Evans, Ingram, Macdonald, and Weber (2009), global education is essential for fostering international understanding and preparing students for active participation in global civic culture. Therefore, this global education should incorporate global values such as peace, human rights, and coexistence (Ishimori, 2013).

Global citizenship is defined as the collective social, political, environmental, and economic actions taken by globally minded individuals and surrounding societies worldwide (United Nations, 2023). Since the term "citizenship" includes rights, responsibilities, and obligations (Davies and Graham, 2010), global education based on this concept has been an essential educational strategy for institutions of higher education since the late 1990s (Hans, 2010). UNESCO also recognizes this value and promotes it as global citizenship education (UNESCO, 2023). This educational concept is already known to have been incorporated into the academic curricula of many countries, and its methods can be divided into two categories: global competencies to acquire the skills necessary for a global society and global consciousness to achieve a worldwide orientation and cultural sensitivity based on human values (Heela and Yemini, 2017).

Since the Global Engineering Development Project (GEDP) started in 2018, Toyota KOSEN has developed several international programs to foster students' global mindset, including their English communication skills as future engineers. Students must acquire knowledge of state-of-the-art technology and learn how this technology affects society. They should be given many opportunities to interact with people with different ideas and backgrounds to solve world issues, projected in a knowledge-based society in the 21st century (Griffin, McGaw, and Care, 2012). The following indicators were established to carry out the GEDP, which started in 2018, and to evaluate the results of the training project. First, TOEIC scores were set as an indicator to assess the improvement of students' English proficiency through the training project. This indicator evaluates the project by comparing the average TOEIC test score of the 4th-grade students every year with the target value. Second, we set the annual number of English written books borrowed from the library, and third, we set the number of students who study abroad for a long period as an indicator, which is also evaluated by comparing it with the target value.

As for the assessment, we have mainly focused on students' English proficiency associated with TOEIC scores (Nishizawa, Kamiya, Ichikawa, Salmasan, and Ohno, 2022). However, many aspects can be seen as they joined other programs, such as collaboration, proactive attitude, or problem-solving skills. As that led us to reconsider our assessments, we have decided to explore students' skills and attitudes toward a global mindset following Ishimori (2013).

In this study, we examine our international exchange activities by conducting a multifaceted evaluation of how the students' global citizenship skills have improved in our school's international exchange activities.

International Exchange Activities

We decided to incorporate the concept of SDGs (Sustainable Development Goals) into the programs as an essential part of pedagogical requirements, hoping that engaging in the programs would lead them to learn SDGs and embody SDGs by themselves (Ichikawa, Matsumoto, Tsuzuki, and Eguchi, 2022). Projects such as the International Exchange Video Contest (IEVC) and TEDxToyotaKOSEN were built on this belief (Table 1). Other programs, such as Thailand-Japan Students Science Fair (TJ-SSF) and the committee for hosting Thai students at Toyota KOSEN were also encouraged to join. In addition, some students participated in long-term study abroad programs of about ten months and short-term study programs of about two weeks.

In the video contest, students were paired with students of the same age from other countries and made online. The co-produced videos were made four times in three months to exchange and improve their production skills. In the fourth contest held last year, the students made a video describing solutions to SDG-related issues faced by private companies.

Table 1. The number of student participants, event period, and preparation period for each international exchange activity.
*: The event was not held in a video contest because students submitted videos they created.

Activities	Number of student's participants	Event period	Preparation period
Video Contest	18	—*	4 months
TEDx Toyota KOSEN	90	1 day	3 months
KMUTT x Toyota KOSEN 1day exchange	60	Half day	1 month
TJ Science Fair	9	5 days	4 months
Lunch Meeting	15	About 1 hour a week though a year	

When 18 students from KOSEN KMUTT of Thailand visited our school, we led them on a school tour and planned and managed a Japanese cultural experience. During the school tour, we provided explanations using specialized terminology. In the Japanese cultural experience, students introduced Japanese culture while communicating with KOSEN KMUTT students.

At the TJ Science Fair held in Thailand, students presented posters in English about their research activities. Seven students presented their research activities related to information engineering in this time.

The second TEDx Toyota KOSEN was held at our college. Students were responsible for most of the planning, organization, and operation. Three speakers from overseas were among the seven, and students coordinated and consulted with them in English. Since the theme was the SDGs, the leader student gave four lectures on the SDGs to deepen understanding.

Assessment Methods

The assessment was the Global Citizenship Assessment proposed by Ishimori (2013). Ishimori (2011) used this assessment to evaluate global education in upper secondary schools and found that the various qualities students acquired through global education were assessed. In addition, the validity of the assessment was confirmed by the fact that the information obtained from the assessment led teachers to improve their classes.

The assessment items were "Knowledge and Understanding," "Abilities and Skills," and "Attitudes, Stance, and Values" (Table 2). Each domain can be divided into three categories with three to four specific indicators. Ten specific indicator items are set for each category, for 30 indicator items. Subjects are required to answer all items. Students answered each idicator items on scale 1 to 5.

This assessment was completed using Microsoft Forms. Students responded to the questionnaire from their smartphones during the meeting and after the event.

Table 2. The domain and category of the assessment sheet students answered before and after international exchange activities.

Domain	Category	Number of indicator
Knowledge and Understanding	Global issues	4
	Diversity and Multicultural society	3
	Global connections and Interdependence	3
Abilities and Skills	Critical thinking and Problem solving	3
	Communication and Collaboration	4
	Information Literacy and Collect or use information	3
Attitudes, Stances, and Values	Self-esteem and Self-awareness	3
	Respect for diversity and Cross-cultural tolerance	3
	Taking informed and responsible action	4

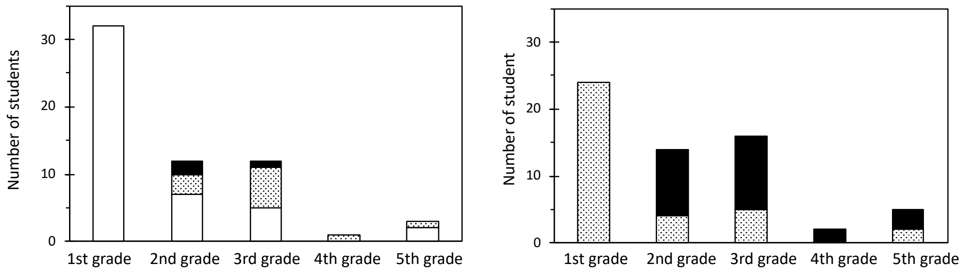

Figure 1. Student number participating in our international exchange activities.
Left: Collected number of before activities, Right: collected number of after activities
The white bar represents a number of no-experience of international exchange activities, and the dotted bar and black bar means once and over twice experience of activities each.

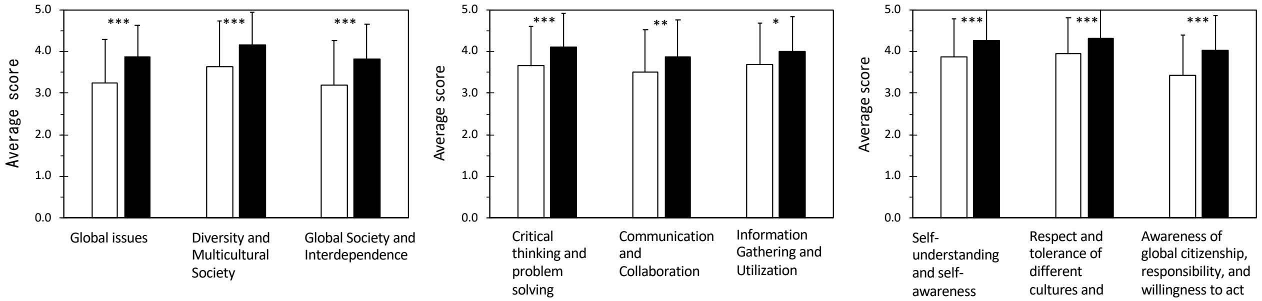

Figure 2. The average score of global citizenship survey results.
Left: Knowledge and understanding, Middle: Abilities and Skills, Right: Attitudes, Stance, and Values
The white bar represents scores collected before international exchange activities, and the black bar does after activities.
*: p<0.05, **: p<0.01, ***: p<0.005

Table 3. The number of collected answers for the assessment held before or after activities.

		Total collected number	Each collected number	Number of students who participated both assessment
Before activities	Having experience of long-term abroad studying	60	6	
	Not having experience of long-term abroad studying		54	
After activities	Having experience of long-term abroad studying	61	7	3
	Not having experience of long-term abroad studying		54	34

Table 4. The number of participating students separated before and after each international exchange activity.

		Video Contest	TEDx Toyota KOSEN	KOSEN KMUTT x Toyota KOSEN 1day exchange	TJ Science Fair	Lunch Meeing
Before activities	No experience	57	35	53	59	55
	Once	3	14	7	1	4
	Several times	0	11	0	0	1
After activities	No experience	52	0	56	60	51
	Once	6	40	5	1	7
	Several times	3	21	0	0	3

The assessment was conducted twice, 1st before the international exchange activity and 2nd after the international exchange activity. The pre-assessment was conducted before the start of all activities except for the lunch meeting shown in Table 3. The post-assessment was conducted after the TEDxToyotaKOSEN event because it was the last event in terms of time.

Figure 1 shows the number of students who participated in the assessment before and after the activity, their respective grades, and their history of international exchange activities. The number of students in grades 1 through 5 in the school year 2022 is 1,134. Sixty students participated in the pre-activity assessment (Table 4). Of these, 77% had yet to experience international exchange activities. Sixty-one students participated in the post-activity assessment, all of whom had participated in at least one TEDx activity. 43% of the students had participated in two or more international exchange activities.

The number of students who responded to the pre-and post-assessment was 36.

Assessment Results

All items were compared before and after the international exchange activities, and the results showed higher values after the activities (Figure 2). By domain,

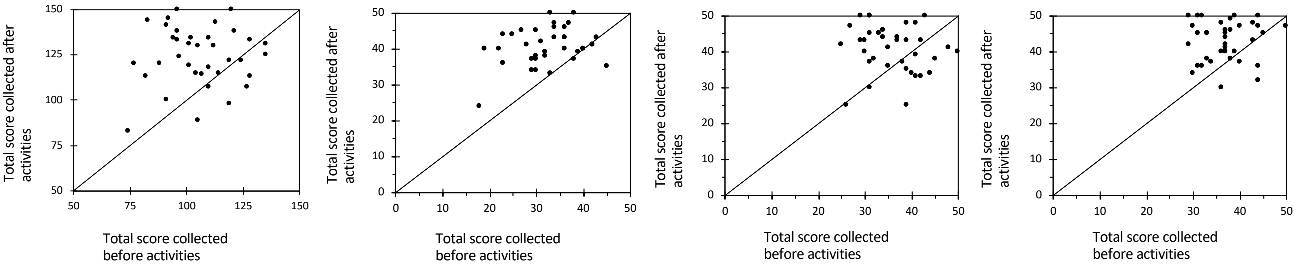

Figure 3. The total score of the global citizenship assessment results in the relationship between before and after international exchange activities.

Left: All scores, 2nd from left: Domain of Knowledge and understanding, 2nd from right: Domain of Abilities and Skills, Right: Domain of Attitudes, Stance, and Values

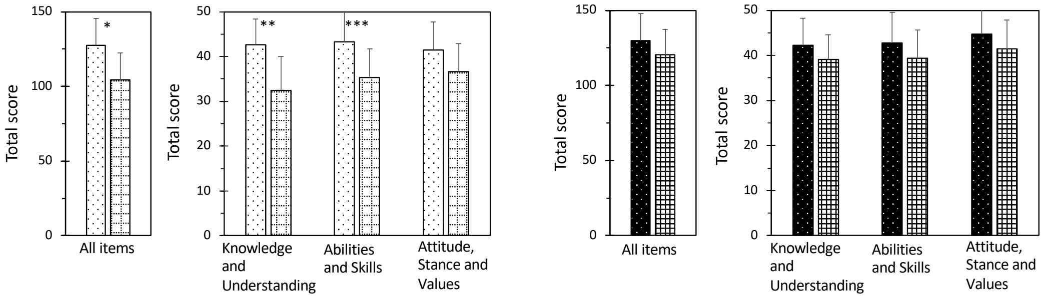

Figure 4. The total score of the global citizenship survey results comparing the experience of a long period abroad studying.

Left two graphs: Collection before activities, Right two graphs: Collection after activities

The dotted bar represents scores of having experiences studying abroad, and the meshed bar scores of not having studying abroad for a long period.

*: $p<0.05$, **: $p<0.01$, ***: $p<0.005$

the most significant difference was 0.6 for "Knowledge and Understanding," followed by 0.5 for "Attitude, Attitude and Values," and 0.4 for "Skills and Skills. The results objectively showed that the international exchange activities were practical regarding global citizenship.

Detailed Analysis Before and After International Exchange Activities

78% of the students who participated in international exchange activities showed that the values after the activities were more significant than before (Figure 3). The average increase in the pre- and post-activity difference was 27 points for students who increased their scores, and the average decrease in the pre- and post-activity difference was 11 points for students who decreased their scores. As for the relationship between pre- and post-activity scores, the distribution in Figure 3 shows little relationship.

By domain, the distribution of scores before and after the activity was relatively biased toward higher scores for "Attitude, Stance, and Values." However, for "Knowledge and Understanding," the distribution shifted toward higher scores after the activity than before, clearly indicating the effect of the international exchange activity. On the other hand, more students decreased their scores in "Abilities and Skills" after the activity than in the other areas.

The international exchange activities contributed to improving global citizenship, with particular growth in "Knowledge and Understanding" and "Attitude, Stance, and Values.”

Relationship between the presence of long-term study abroad and improvement in ability

When we compared the scores of students who had studied abroad and those who had not studied abroad before the international exchange activities, the average score of those who had studied abroad was 128 points (Figure 4). The average score of those who had not studied abroad was 104 points, showing a significant difference between the two groups. In particular, there was a clear difference between the two domains of "Knowledge and Understanding" and "Abilities and Skills.” On the other hand, when the scores of them were compared after the international exchange activities, those who had studied abroad scored an average of 130 points. In comparison, those who had not studied abroad scored 120 points, showing no significant difference between the two groups. The score difference between the two groups was smaller than before the international exchange activity. The scores of those who had never studied abroad increased, while those who had studied abroad remained almost unchanged. In addition, after the international exchange activities, the scores for all domains were similar between those with and without experience.

Comparing the scores between those who had studied abroad and those who had never studied abroad before and after the international exchange, the average score of those who had studied abroad after international exchange activities was 134 points, and the difference between before and after activities was 4 points. On the other hand, those who had never studied abroad scored 121 points after the activity, and the difference before and after the activity was 14 points, indicating a significant difference between the experience of the activities. These results indicate that on-campus international exchange activities effectively develop global citizenship for those not studying abroad.

Conclusions

This study aimed to verify the international exchange activities by conducting a multifaceted assessment of how the students' global citizenship skills improved due to the international exchange activities conducted at Toyota KOSEN. The assessment results before and after the international exchange activities showed that the scores were significantly higher after the international exchange activities, confirming that our activities contributed to improving global citizenship. It was also confirmed that our activities improved "Knowledge and Understanding" and "Attitude, Stance, and Values." Furthermore, when the pre- and post-activity values were compared by whether the students had studied abroad for a long period, those who had studied abroad for a long period showed a slight improvement in their assessment values. In contrast, those who had not studied abroad for a long period showed a significant improvement. These results indicate that international exchange activities on campus foster global citizenship in students who have yet to study abroad and are effective enough to complement the long-term study abroad experience.

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Case Studies of Laboratories Using the Concept of "Remote Island Engineering" to Motivate Students to Research and Solve Local Problems

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Abstract

Kamijima Town, where the National Institute of Technology, Yuge College (NITYC) is located, is a municipality consisting of remote islands in the Seto Inland Sea. We propose the concept of "remote island engineering". This concept is to solve island problems through an engineering approach, making full use of the island's resources and human resources, as well as the technical capabilities of the NITYC. At the NITYC, this concept of "remote island engineering" has been spreading from faculty to students over the past few years. Our laboratory involves 5th-year students, sometimes with lower-level students and residents, in helping to solve regional issues as part of their graduation research.

For example, there are many abandoned bamboo forests in Kamijima Town, which are not well managed due to the aging of the population. Therefore, our laboratory proposed the "cascading of bamboo" and came up with a method of using it in stages. As the primary use, bamboo houses designed by students are built, and as the secondary use, bamboo charcoal is made from the bamboo used in the bamboo houses. They also experimented to use bamboo charcoal as a fishing reef by sinking it in the sea. Furthermore, remote islands are likely to be isolated in the event of a disaster due to the disruption of lifelines. For this reason, the company is actively involved in disaster prevention and mitigation themes. One such theme is the "development of portable power generation equipment". This is a combination of a rocket stove, which attracted attention after the Great East Japan Earthquake, and a Stirling engine, an external combustion engine, mounted on a cart so that it can be carried by human power. The students were responsible for all the design and manufacturing for this development.

This paper shows that laboratory management based on "remote island engineering" produces the educational outcomes of "independent spirit" and "cooperation with others" when students work on their initiative and take responsibility for their research. Students can experience the practice of the "PDCA cycle," in which they identify issues, set goals, gain new knowledge through experiments and observations, and present their findings at regular meetings to confirm the direction of the project. By having the students experience this cycle for one year, they were able to spend more time in the laboratory and conduct high-quality graduation research.

Keywords: *Remote Island Engineering, Regional Revitalization, Resource Circulation, Self-motivated Learning, Graduation Research*

Introduction

"Remote Island KOSEN" The most important aspect to consider when contemplating their significance is differentiation from other educational institutions. Since the introduction of the Model Core Curriculum (MCC) in 2018, the desired content for teaching by each faculty member and the content that students wish to learn have been organized (1). As a result, the National Institute of Technology (KOSEN) has taken on a stronger role as higher education institution where a certain level of education can be obtained regardless of the school chosen. On the other hand, many KOSEN have been struggling with a decrease in the number of applicants due to the significant impact of a declining birth rate in recent years. Therefore, each KOSEN is making efforts to utilize the unique characteristics of their campuses and focus on initiatives to secure a sufficient number of students. The recent establishment of "Kamiyama Marugoto College of Design, Engineering, and Entrepreneurship" is still fresh in memory. This KOSEN has made a good start with an applicant ratio of 9.1 times, fully focusing on the distinctive axis of "fostering start-up human resources and regional development." The logic that people won't come just because it is located in a rural area no longer holds true. Instead, it is believed that nurturing talents who can explore the strengths of rural areas and work towards solving regional issues is the next step for the KOSEN scattered across 55 locations nationwide, paving the way for the next generation.

The author's affiliation, NITYC, is one of the regional KOSEN and is located on a remote island in the central part of the Seto Inland Sea. While there are nearly 250 inhabited islands in Japan, apart from Okinawa, there are very few remote islands that have higher education institutions such as universities or KOSEN (2). Therefore, they can be considered precious establishments. Considering this situation, NITYC advocates for the promotion of practical education that utilizes the characteristics of remote islands, which is referred to as "Remote Island Engineering." It involves addressing the island's challenges by leveraging the island's resources, talents, and the technical expertise of the KOSEN to solve them through an engineering approach. The objectives of this education are to contribute to the local community and cultivate talents who can lead new industries. It is important for students to have confidence that they have solved local issues by utilizing the knowledge and skills they learned at KOSEN (3).

The authors' laboratory conducts graduation research on the theme of "Remote Island Engineering". Every year, fifth-year students choose their research laboratory, and the faculty members of each laboratory either assign research topics to the students or allow them to specify their own topics. The research is carried out over approximately one year. In the Department of Electronic and Mechanical Engineering at NITYC, the approach to graduation research is left to the discretion of the supervising faculty members. While the faculty members aim to produce high-quality graduation theses, it is not uncommon for the progress of research to be hindered by the characteristics and motivation of assigned students, which can create a significant burden on the supervising faculty members. In the past, this laboratory has been searching for ways to convey the appeal of research to such unenthusiastic students and encourage them to independently discover issues, consider methods, and take approaches. Recently, by making the theme of our laboratory consistently related to "Remote Island Engineering," we have been able to attract students who are interested in contributing to the local community and the natural environment of remote islands. As a result, in the graduation research projects conducted in the past two years, we have seen the ideas and intentions of the supervising faculty members permeate the research, leading to achievements such as winning awards in academic presentations.

This paper introduces two examples of graduation research projects: "Development of Portable Power Generation Equipment for Disaster Prevention and Mitigation" and "Improvement of Marine Environment through Cascading of Bamboo." Both topics were chosen by the students themselves, who were responsible for designing and conducting experiments and persevering through failures until completing their research papers. Of course, there are times when students' motivation wanes along the way. However, even in such situations, the teachers did not present methods, but only gave hints, and instilled the mindset that "research is not something imposed on them but something they must take on themselves." By adopting this approach, the students are encouraged to take ownership of their research and understand that it is their responsibility to tackle the challenges. The teachers provide guidance and support as needed, but the emphasis is on fostering a sense of autonomy and self-motivation.

Here are the guidelines of our laboratory:

1. During the initial meeting, we conduct a brainstorming session with all members to generate multiple problem statements and approaches based on "Remote Island Engineering."
2. Through the first semester, we encourage each team to work on two or three research themes simultaneously rather than narrowing them down to a single topic. Additionally, if another team requires assistance with their project and manpower, teams collaborate and support each other.
3. Every two weeks, we hold progress report meetings. Each team presents their findings for approximately 10 minutes using PowerPoint slides, and all members attend to provide feedback and engage in discussions.

1st Case Study: Development of Portable Power Generation Equipment for Disaster Prevention and Mitigation

In response to the challenge of "ensuring infrastructure during disasters" faced by remote islands like Kamijima Town, which heavily relies on mainland supplies for essential resources like water and electricity, students conducted a graduation research project on the development of a portable power generation system that combines a rocket stove, which can be easily produced even in disaster-affected areas and used for cooking food and heating, with an external combustion engine known as a Stirling engine. The research group consisted of three members, with roles divided into leader, designer, and electrical engineer.

The research project utilized an ADMIEXCO company's 90-degree V-gamma type water-cooled single-unit Stirling engine, as shown in Figure 1. The rocket stove was newly made to be adapted to this engine and with an insulated structure and durable design. Additionally, the dedicated framework was designed so that all other power generation units and cooling water tanks could be mounted on the cart, and a 3D model was created as shown in Figure 2. The CAD software used for this purpose was Autodesk Fusion 360, obtained through an educational institution's free license.


Figure 1. Appearance of ADMIEXCO company's Stirling engine

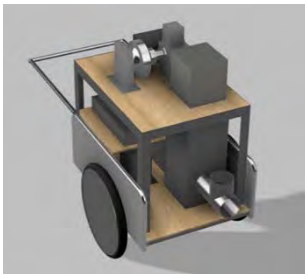
Figure 2. 3D model of the portable power generation equipment

The first step, they took was to investigate the mechanism and structure of the Stirling engine. Although the students had learned about the Carnot cycle in their fourth-year thermodynamics class and were familiar with the operating principles of the Stirling engine, it was their first time interacting with a real engine. Therefore, they conducted research on literature related to the Stirling engine. Additionally, they performed multiple operating tests on the ADMIEXCO company's Stirling engine, which was planned to be installed, to determine the operating temperatures and amount of firewood needed.

A distinctive feature of this group was that, on completing the experiments, the students voluntarily engaged in brainstorming sessions to discuss and consolidate the identified issues, along with their corresponding solutions and insights. This process occurred without direct instruction from the teachers, as the students took the initiative to carry it out.

In the next step, they proceeded with the making of the rocket stove. A rocket stove is a combustion device that consists of an insulated exhaust pipe (heat riser) and a combustion chamber (burn tunnel), which uses wood or similar materials as fuel. When the fuel placed in the burn tunnel ignites, wood gas is generated, and this combustible gas undergoes secondary combustion within the heat riser. As a result, a chimney effect is created, leading to a strong updraft inside the heat riser. The updraft creates a negative pressure in the burn tunnel, causing outside air to be drawn into the burn tunnel through the fuel inlet. This enhances combustion efficiency, resulting in exhaust gases approaching near-complete combustion. Professor Ito, who is one of the co-authors of this paper, had previously conducted research on rocket stoves and possessed a simplified version using an 18-liter square can. However, the students decided to design and make a new rocket stove for this project.

The concept for the rocket stove is as follows:

1. Design and make the stove from scratch.
2. Ensure it has the strength to withstand long hours of operation.
3. Extend the length of the heat riser section compared to existing models to improve efficiency.
4. Implement thorough insulation to enhance efficiency.

Following the above concept, the students went through a series of trial-and-error iterations, and the new rocket stove was completed. Figures 3 to 5 show the sequential steps of the process and the final product of the rocket stove. A comparison of the combustion temperature was conducted between the new rocket stove and the existing rocket stove, as shown in Figure 6. It demonstrates that the new rocket stove achieved stable combustion at approximately 700 degree-C for about 10 minutes, surpassing the existing model by providing stable combustion at higher temperatures.

Furthermore, the team proceeded with the making of the framework, making of an insulation container to efficiently transfer the heat from the rocket stove to the Stirling engine heating unit, assembly on the cart, and installation of electrical components. As a result, "Portable Power Generation Equipment" as shown in Figure 7 was completed. The students presented this achievement at the "Hyper Interdisciplinary Conference in Tokyo 2022" and received the "Monozukuri Research Center Award" from the organizing company, Leave a Nest Co., Ltd.

It is rare for the year-long efforts of a graduation research project to culminate in an award at a conference. However, even without the award, these students were highly satisfied with their research outcomes. They continued conducting operational experiments with the completed device until just before the paper presentation. Unfortunately, they were unable to acquire data on power generation for that year, but this task was passed on to the following year. The student who led the development team later remarked, "The experience of building something from scratch in this laboratory was incredibly valuable."

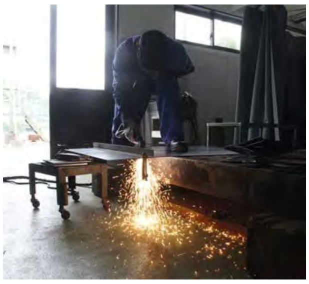

Figure 3. Cutting the steel plates

Figure 4. Welding the steel plates

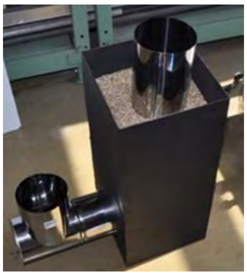

Figure 5. The final product of the rocket stove

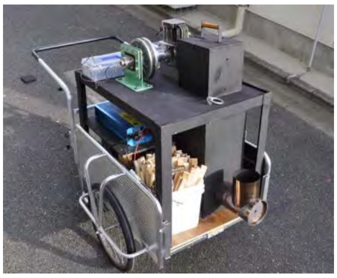

Figure 7. Appearance of "Portable Power Generation Equipment"

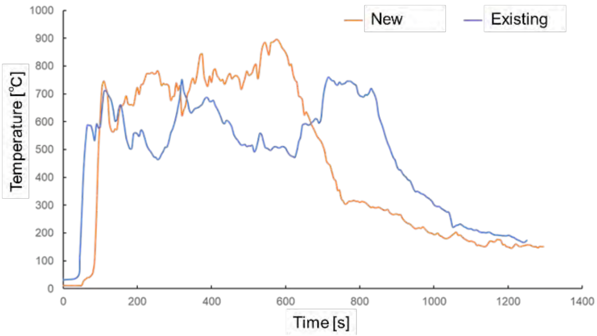

Figure 6. The comparison of the combustion temperature between the new and the existing rocket stove

2nd Case Study: Improvement of Marine Environment through Cascading of Bamboo

In the author's laboratory, we advocate for the concept of "Cascading of Bamboo" as a method to give added value to the increasing amount of abandoned bamboo on the island and actively promote its harvesting and management. Cascading involves multiple stages of recycling, starting from high-quality recycling and gradually transitioning to lower-quality recycling, with the aim of utilizing biomass resources effectively (4). Over the years, all members of the laboratory have been actively involved in harvesting bamboo from abandoned bamboo forests near the school and exploring various ways to utilize it.

For example, among the harvested bamboo, the ones in good condition were used as materials to construct a bamboo house. This was a project proposed by one of the members involved in the "Cascading of Bamboo" initiative, and this student took the lead in designing and assembling the house. Figures 8 and 9 show the actual bamboo house that was built.

In addition, bamboo charcoal was produced from the harvested bamboo, including the primary used for the bamboo house construction. Bamboo charcoal serves as a biomass fuel and is also utilized as a deodorizer and moisture absorber due to its fine pores on the surface. The potential of these fine pores in bamboo charcoal to improve marine environments was investigated in the graduation research project. Such marine-related topics are highly relevant and accessible for NITYC, a KOSEN located on an island. The students enthusiastically conducted fieldwork and made an interesting discovery when they retrieved the bamboo charcoal submerged in the sea at the pontoon. Therefore, they found that numerous microorganisms had attached to it. The results of this experiment indicate that submerging bamboo charcoal in the sea can be expected to be effective as a fish reef where microorganisms attach and eventually attract small fish that prey on the microorganisms. This achievement was presented by the students at the "Hyper Interdisciplinary Conference in Osaka 2022" as shown in Figure 10.

Furthermore, inspired by the research achievements of their seniors, the current members of the graduation research team have engaged in discussions and are tackling the creation of fish reefs using bamboo and bamboo charcoal. It is evident that the new members have been influenced by the research accomplishments of their seniors.

Figure 8. Assembling the bamboo house

Figure 9. Joint part

Figure 10. Poster presentations at conferences

Conclusions

As mentioned above, the author's laboratory has incorporated the theme of "Remote Island Engineering" in graduation research, enabling students to identify their challenges, devise approaches, actively learn, and publicly present their findings. The students formulate research plans, put them into action, sometimes face failures, and present their progress at progress report meetings to receive feedback from teachers and colleagues. Through this iterative process, a "PDCA cycle" naturally takes shape, empowering students to autonomously advance their research toward problem-solving.

Even more, collaboration with the local community is essential in solving local problems. In the author's laboratory, it has become a gathering place for various activities involving residents, including Mr. Kaneto, a co-author who actively participates as an islander, and students from nearby Yuge High School. It is important to create a laboratory that is accessible to both students and residents, where everyone feels welcome to participate.

Acknowledgements

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International exchange between Thai and Japanese students as a part of an environmental research project

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Abstract

The National Institute of Technology, Yuge College (NITYC), and Nakhon Phanom University (NPU) have formed a partnership and been participating in short-term exchange programs. During a short-term exchange reported here, we worked on a project to develop a system for conducting surveys of the Mekong River. The present project focuses on the development of an Arduino-based water supply and water quality survey system. Our students are also engaged in research, presentations, report writing, and recreational activities with Thai students to enhance their skills as international engineers. Here we also report a survey conducted to evaluate the project's effectiveness.

Keywords: *International exchange, Cooperative study, Environmental research, Technical cooperation, Water-quality survey*

Introduction

National Institute of Technology, Yuge College (NITYC) has signed an agreement with Nakhon Phanom University (NPU). NITYC is located near the Inland Sea, while NPU is near the Mekong River. For this reason, the two schools have continued to engage in international exchange activities related to environmental studies and participated a joint development project of an "autonomous research vessel”. In recent years, NPU students from the Department of Electrical Engineering and Technology and NITYC students from the Department of Information Technology and the Department of Electronic and Mechanical Engineering have also collaborated on research projects in NPU's Nursing Department.

In the project reported in this paper, the students tackled a new issue focusing on the water quality of the Mekong River, which is undergoing remarkable environmental changes due to dam construction and other factors. The students from both schools have developed a water quality survey system and conducted an on-site survey of the Mekong River's water quality. They have created a "water supply system" and a "pH survey system" using Arduino, and conducted a survey on the water quality of the Mekong River. In addition, they carried out a review on related research papers, gave presentations on their findings, and prepared reports. Besides that the participated students have had experiences correlated with becoming international engineers as they had local cultural exchanges such as dinners and temple visits.

In this paper, we report an overview of the international exchange and the current status of the Mekong River. Next, we report on the results of the most recent water quality survey and other exchange projects. Furthermore, the results of the awareness survey questionnaires conducted on students before and after the international exchange will be presented, and a summary of this project will be given.

NITYC and NPU

NITYC is a college located on an island of Seto Inland Sea in Japan, and is located next to the sea, as shown in Figure 1.

Figure 1. Sea near NITYC

Figure 2. Mekong River near NPU

The NPU is located near the Mekong River in Thailand as shown in Figure 2. Both schools have continued to conduct research utilizing the characteristics of their respective locations, such as the development of an environmental research boat, through short-term student study abroad projects. In this project, students from the two schools exchanged techniques on issues related to water quality research.

Thailand and Mekong River

The Mekong River flows from southern China through the borders of Thailand and Laos, passing through Cambodia and Vietnam before emptying into the South China Sea. The Mekong River is the longest river in Southeast Asia, with a total length of 4,620 km. It is an important river for the Thai people, who need it for fishing and agriculture.

In recent years, many dams have been constructed upstream of the Mekong River, which has drastically changed the environment of the Mekong River basin. Water quality has also begun to change drastically in some places, and the river, which previously was brown, has now turned blue. Therefore, monitoring of environmental changes is essential for the sustainable development of the Mekong River Basin. NITYC and NPU are continuously developing environmental survey boats to monitor the Mekong River's topography.

Past exchange results

Yuge College and NPU have exchanged 5 times. Table 1 shows the implementation years, the number of students of Yuge College and major developments. We have been developing the environmental research boat continuously for 10 years since we started this program. In 2013, we had reported the results of this ongoing project. Also, we reported at an international conference in 2015.

Table 1. Exchange results

Implementation year	Number of students	Major Developments
2012	7	Environmental Research Boat
2014	7	Environmental Research Boat
2016	4	Nursing Equipment
2019	6	Nursing Equipment
2022	4	Water-quality survey

In order to carry out the 2022 exchange program reported here we had a round trip from Fukuoka to Bangkok and Nakhon Phanom, Thailand. During our stay in Bangkok, we also visited Ayutthaya and learned about cultural differences.

In Nakhon Phanom, the students from NITYC and NPU worked together to survey the water quality of the Mekong River with an "Environmental Survey Boat," in which students from NPU's Department of Electrical Engineer and NITYC's Department of Electronic and Mechanical Engineering and Department of Information Technology collaborated to develop a water quality survey system and as a result they assessed the quality of the river.

Below is an introduction to our project.

Results of Existing Projects

1. Development of environmental research boat

Based on the autonomous navigation algorithm developed by Prof. Tabusa et al, a new algorithm was developed to survey the river bottom of the Mekong River. The development is still ongoing.

Figure 3 shows past experiments on the Mekong River.

Figure 3. Experiment on the Mekong River

2. Joint Development with the Department of Nursing

In 2016, we developed a massage pillow for pregnant women, as shown in Figure 4. In 2019, we developed a nursing device for people with leg injuries, PUSH IT UP, as shown in Figure 5. In this project, we first interviewed students in the Department of Nursing about the challenges they faced, then the actual hardware was created by students in the Department of Electrical Engineer, the software control was done by students in the Department of Information Technology, and the device design was created by students in the Department of Electronic and Mechanical Engineering.

Figure 4. Maternity pillow

Figure 5. PUSH IT UP

Outline of this project

In this project, NITYC students and faculty traveled to Thailand for 10 days from December 18, 2022 to work on a project with NPU students and faculty. The flow of this year's project is as follows.

1. Presentation to introduce the schools
2. Discussing the water quality survey system to be developed
3. Construction water supply system and pH survey system
4. Water sampling and water quality survey in the Mekong River
5. Summary and presentation of results
6. Preparation of report

In addition, international exchange recreation and facility tours were conducted during the project. In addition, the students were given questionnaires before and after the project.

Water Quality Survey Experiment and Development of Water Supply System

Using arduino, a microcomputer device, the students from both schools developed an automatic water supply system shown in Figure 6 and conducted a water quality survey experiment on the Mekong River. The software control was done by the students of the Information Technology Department, and the design of the device was done by the students of the Electronics and Mechanical Engineering Department. The students of NPU created a pH investigation device and shared their procedures. The water quality survey scene is shown in Figures 7 and 8.

In the experiment, water samples were collected at two points in the Mekong River, one where domestic wastewater flows and the other where clean water flows, and water quality was investigated. The items investigated were pH, chemical Oxygen Demand, Iron, Total Hardness, Nitrite, and E. coli. The students presented these findings in English and compiled them into a report. The results of this survey will be studied as basic data for future exchange projects.

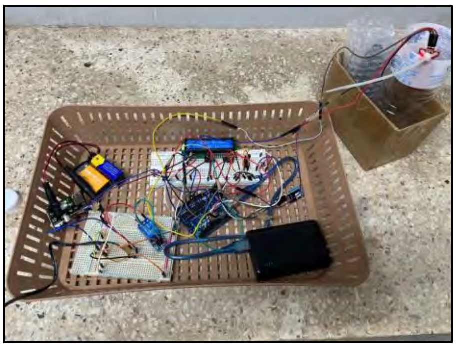

Figure 6. Automatic water supply device developed

Figure 7. Water sampling at the Mekong River

Figure 8. Water quality survey

Cultural exchange and tours

In addition to the projects described in the previous chapter, the students also participated in cultural exchanges and facility tours. Our students visited facilities on the NPU campus, the temple in Nakhon Phanom, and the New Year's Festival. This short-term program took place in December, a special time of year when the New Year's Festival is celebrated.

Our students interacted with NPU students as part of an international exchange by observing the festival lights, walking around the town, and having meals together. NPU students also gave a lecture on how to visit temples in Thailand.

Figure 9 shows a scene from the exchange meeting.

Figure 9. Scene of students being taught how to visit Thai temples

Questionnaire Results

Questionnaires were administered to students before and after their short-term study abroad. This chapter summarizes the results of the questionnaires before and after the study abroad program. This questionnaire was compiled with reference to the Japan Student Services Organization's (JASSO) questionnaire for exchanged students, which was answered on a 5-point scale (1. Disagree to 5. Strongly Agree). The questionnaire is presented below, with results for students supported by JASSO from 2016 to 2022.

a. Able to take the initiative in finding issues that need to be addressed
b. Able to reach out to peers and take action to improve problems together
c. Think about the solution process for an issue and execute it in a planned manner
d. Able to take a leadership role in different places and within one's own cultural background
e. Able to actively communicate the meaning of a foreign language, even if it is inadequate
f. Understand and accept people who have different faiths and cultural backgrounds from their own
g. Have a strong motivation to study their area of expertise
h. There is motivation to study linguistics
i. Have a clear idea of the future direction and career path

A graph summarizing the average results of the 13 students' questionnaires is shown in Figure 10. Comparing the results before and after our project, all items were confirmed to have improved. In particular, items d and e have improved significantly. This indicates that the students have grown to be able to communicate actively even if they are not sure about their foreign language skills.

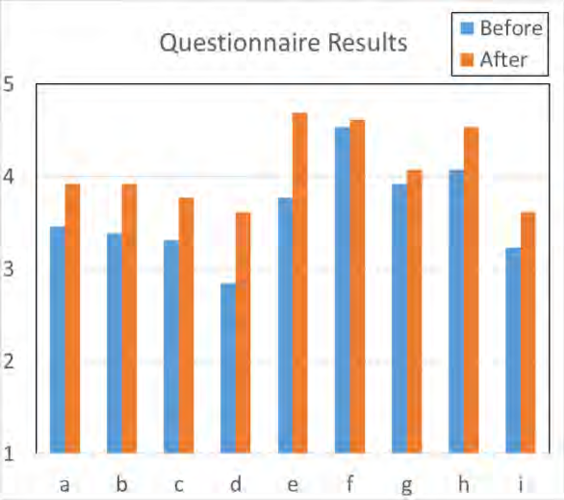

Figure 10. Questionnaire Results

Conclusions

This paper summarizes the results of the short-term exchange program between NITYC and NPU. In this project, we developed a new initiative to study the water quality of the Mekong River.

Through our exchange program, our students gained international communication skills, leadership, and important experience to become international engineers.

Acknowledgements

The projects were supported by the Japan Student Services Organization (JASSO) Student Exchange Support Program and Yuge College Fund for Advancement of Science and Technology. And this project was made possible through the generous cooperation of Nakhon Phanom University.

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Engaging Learners in Online Asynchronous Learning (OAL)

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Abstract

The pandemic has accelerated the adoption of technology-enabled learning in many educational institutes to allow students to continue their learning despite closure of the physical campus. One of Ngee Ann Polytechnic's responses to technology-enabled learning is to leverage flipped learning where students learn content via Online Asynchronous Learning (OAL) packages independently and apply that knowledge during In-Person Learning (IPL) sessions on campus.

This study aimed to investigate the effectiveness of OAL to engage learners using Learner-centered Learning (LcL) design to allow for multi-faceted feedback, use of gamification element, collaborative learning, opportunities for application of learning in OAL and the use of OAL features such as multimedia-rich resources and ease of access to learning materials in the Brightspace Learning Management System (LMS) environment.

The study adopted a mixed-method approach, which included an analysis of the student's perception of their engagement level with learner-centred OAL designs as well as data generated from the LMS. The results showed a significant increase in learner engagement in the OAL especially in learning activities such as discussion forums and quizzes. Feedback from students on the use of badges as a form of reward was generally positive, and they appreciated the weekly consultation hosted in the Bongo virtual classroom. The study provided reflections and insights into the effectiveness of the features and learner-centred approaches. One suggestion is to include different tiers of badges for different levels of participation as well as a system to exchange badges for rewards to further incentivise the students. For future enhancement, the author is considering further dividing the learning content into more manageable bite-size segments and exploring text-based AI, which could engage students in extending their learning.

The study concluded positively on the effectiveness of the features and learner-centred approaches used in engaging learners in OAL and highlighted the need for future research on the OAL implementation in courses and the efficacy of the platforms used.

Keywords: *Student engagement, Online Asynchronous Learning, flipped learning*

Introduction

The COVID-19 pandemic has disrupted education systems worldwide, forcing many educational institutes to transit from traditional classroom settings to technology-enabled learning (Asgari et al., 2021). Ngee Ann Polytechnic (NP) is one such institute that has responded to this challenge by leveraging on flipped learning (Bishop & Verleger, 2013), which involved students learning content independently through Online Asynchronous Learning (OAL) packages and applying that knowledge during In-Person Learning (IPL) sessions on campus. This approach has gained traction due to its flexibility, which allows learners to engage with content at their own pace and convenience. However, for OAL to work, students need to actively engage with the materials before IPL.

In recent years, there has been a growing focus on the learner-centered approach, which prioritizes the learners' individual needs, interests, and experiences in the educational process (Moate & Cox, 2015). Learner-centered Learning (LcL) designs aim to provide a personalized and interactive learning experience that engages learners in various ways, such as through feedback, gamification, and collaborative learning. In this study, we aim to investigate the effectiveness of OAL in engaging learners using LcL design.

As such, this study aims to address the above by considering the following research questions:
1. What are the LcL design considerations in the OAL environment?
2. How to measure the effectiveness of OAL in engaging learners using LcL design?

Module and Student Profile

The Embedded Systems (ES) module is offered to second year students enrolled in two different diploma courses, namely the Diploma in Biomedical Engineering and the Diploma in Engineering Science. This module introduces students to the fundamentals of modern embedded systems, including the basic processor architecture and the concept of System-on-Chip (SoC). This module also covers the use of the C programming language in modern embedded systems and is supplemented by a microcontroller kitset, either in a physical or simulated digital form. The kitset utilizes a microcontroller unit (MCU) to demonstrate the basic hardware interfacing architecture of a typical integrated microcontroller SoC, including input/output, interrupts, analogue-to-digital converter (ADC), timers, and serial communication, among other concepts. Through the ES module, students would be able to gain a strong foundation in embedded systems, preparing them for a range of real-world applications in the biomedical engineering and engineering science fields. The period of study spanned two semesters, catering to 54 students from the Diploma in Biomedical Engineering in the April 2022 semester, and 107 students from both the Diploma in Biomedical Engineering and Diploma in Engineering Science in the October 2022 semester. The implementation of the LcL design varied between the two semesters, specifically, the award of badges and in-class readiness check quizzes was absent in the April 2022 semester. Additionally, the utilization of multiple platforms characterized the April 2022 semester, with Microsoft Teams used for online consultation, recording, and project peer review. In contrast, Brightspace LMS was utilized for the purposes of announcement dissemination and access to all learning materials. However, in the subsequent October semester, a concerted effort was made to streamline all educational activities within the Brightspace LMS, consolidating various functions into a single, comprehensive learning platform.

Brightspace LMS

Brightspace is a cloud-based Learning Management System (LMS) developed by D2L Corporation and is designed to support the delivery of education and training programs. This LMS offers a range of tools and features to assist educators in creating and managing online courses, delivering personalized learning experiences and monitoring student progress (D2L Brightspace, n.d.).

In Singapore, the five polytechnics and the Institute of Technical Education (ITE), collectively known as POLITE, have adopted Brightspace LMS since 2021. At Ngee Ann Polytechnic, all modules' content was migrated to Brightspace LMS starting from the April 2021 semester. The author of the paper has utilized the tools provided in Brightspace LMS to create and organize module materials, which include lecture handouts, videos, practical and practice worksheets, quizzes, assignments, discussion forums, and virtual classrooms. In addition, the author has embraced the use of dashboard in Brightspace LMS to monitor class engagement and progress through real-time learning analytics captured within the LMS.

LcL Design

Learner-centered learning (LcL) is a teaching and learning approach that prioritizes the learner's needs and interests. In LcL design, the teacher becomes a facilitator, providing resources and guidance to support students in their learning journey. The key principles of LcL design include: (1) focus on the learner; (2) active learning; (3) collaboration; (4) feedback and reflection (Weimer, 2013). By incorporating these principles, LcL design fosters student agency, self-directedness, and engagement, which ultimately promotes learning and growth. The LcL designs in OAL were implemented according to these key principles, which were further elaborated below.

1. Focus on the learner

The LcL design aims to create a learning environment that is engaging, personalized, and tailored to the needs and interests of the learner. To achieve this, two considerations were incorporated in the OAL design, i.e. creating an enjoyable learning experience and making learning materials easily accessible to students on the mobile platform.

To make learning enjoyable, the gamification elements, such as badges and secret bits of media, i.e. Easter eggs (MakeUseOf, n.d.), were used to enhance the learning experience in the Brightspace LMS. These elements were used to increase motivation and engagement by providing students with clear goals and rewards for their achievements. For instance, badges will be issued to the learners when they participated in the discussion forum (e.g. post a question or answer a question), or when they obtained full marks for any of the revision quizzes. And the idea of Easter eggs (i.e. hidden media in the LMS) will further encourage students to explore the module content within the LMS. By incorporating these elements, the LcL design aims to create a fun and engaging learning experience that promotes extrinsic motivation and encourages students to take an active role in their learning.

According to Statista (Published by Statista Research Department & 19, 2023), the smartphone penetration share reached about 92 percent in Singapore, indicating that it is a leading country for the use and engagement of smartphones. Therefore, to effectively engage learners in the OAL environment, it is important to ensure ease of access to all their learning within one platform, and also options for students to access learning via their mobile devices. The Brightspace Pulse app (i.e. the mobile companion of the Brightspace LMS) enables students to "learn on the go". The learning materials such as PowerPoint presentations, documents, and videos, as well as hyperlink virtual classroom recordings, can be accessed from within the app without the need to download them. This reduced the time and effort needed to find and access learning materials, enabling students to focus more on the learning itself. With the LcL design principles of making learning more accessible, it aims to increase student engagement and motivation, which ultimately promotes learning and growth.

2. Active learning

Active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing, through hands-on activities, group discussions, and other interactive experiences (Prince, 2004). The goal of active learning is to promote understanding, retention and deepening of knowledge and skills, by providing students with opportunities to apply what they have learnt in meaningful ways.

Active learning strategies are utilized in the design of OAL to engage students learning during OAL. Some of these strategies include the use of web simulator (e.g. Tinkercad ("Tinkercad", n.d.) which has been found to be effective in improving students' programming & computational thinking, theoretical concepts and practical skills (Silva et al, 2019).

In addition, other active learning strategies such as the use of a variety of multimedia resources, such as embedded videos, documents, quizzes, and discussion forums encouraged interaction and student participation in the learning process. A diversity of resources can be used to provide students with different types of learning experiences, such as visual, auditory and kinesthetics, which can help to engage students with diverse learning styles. LcL design principles of providing a variety of resources, it can help to create a dynamic and interactive OAL environment, where students can engage with the material in meaningful ways.

3. Collaboration

Collaboration emphasizes the importance of cooperative interactions among students and between students and teachers to achieve learning goals. Collaboration is essential in creating a learning environment that promotes LcL, fosters a sense of community and shared responsibility for learning. (Bruffee, 1993). In an OAL environment, the collaborative learning would have to take into consideration the online tools & resources to enable collaboration.

Discussion forums is one way to bring students together to discuss/comment/ share their views on specific topics. To better organize the discussion threads, topics were created in the discussion forum according to the units covered in the module. Students can then post their questions accordingly. Discussion forum had been used to promote student engagement, facilitate peer-to-peer learning and provide opportunities for teachers to provide feedback and guidance. They also provide a space for students to ask questions and receive support from their peers and teachers.

Another approach to promoting collaboration is through peer review activities. Peer review enables students to learn from one another by providing feedback on one another’s work. In this module, peer review was infused into the individual project component by integrating FeedbackFruits ("FeedbackFruits," n.d.) into Brightspace LMS, which allows for anonymous and structured peer feedback. Through peer review activities, students can develop important skills such as critical thinking, communication and collaboration.

4. Feedback and Reflection

Feedback is an essential component of the learning process and provides students with the information they need to understand their progress and make improvements (Boud & Molloy, 2013). Reflection, on the other hand, enables students to think critically about their learning experiences and make meaning of their learning.

In LcL design, feedback and reflection can take many forms. Underpinned by the flipped learning approach, this module offers multi-faceted feedback for in-class readiness check quizzes, end of topic revision quizzes (with unlimited attempts) as well as additional worksheets to extend learning. On top of that, discussion forums, activity feeds, and virtual classroom sessions provide students with opportunities to receive feedback and guidance from the teachers or peers. These platforms can be used to discuss course content, ask questions and receive feedback on assignments and assessments.

In addition to feedback, reflection is also an important component of the LcL design. This was covered in the individual project of the module in the forms of double-blind peer review, where students rated each other project presentation video anonymously. With the feedback that comes from a peer, it increases the acceptance of the students and triggers reflections which leads to a deeper understanding of their learning processes, areas for improvement as well as the promotion of ownership and self-regulatory.

Quizzes are one form of feedback that can be utilized by both educators and learners to evaluate their performance. Regular feedback enables students to understand how well they are progressing, which in turn may inspire them to become more motivated and engaged in their studies. In the context of OAL, in-class readiness check quizzes can offer a swift and convenient method to assess students' comprehension of the course content. With real-time quiz statistics, educators can swiftly address any misunderstandings or misconceptions and provide specific feedback to enhance students' understanding. Additionally, asynchronous revision quizzes can be implemented to reinforce students' comprehension of each topic. These quizzes provide an opportunity for students to review the material, identify areas of weakness, and make necessary improvements to their learning progress.

Results and Discussion

Increased Discussion Forum Participation

One notable outcome of the LcL design was increased participation in the discussion forum as shown in Figure 1. Throughout the October 2022 semester, a total of 39 threads were created and 81 replies were posted across 7 topics covered in the module. This represented a significant increase in participation compared to the previous semester in April 2022, where only 1 thread was created and 1 reply was posted across the same number of topics.

The average read (number of posts) per learner in the October 2022 semester was 11.0833, indicating that students were actively engaging with the content and one another in the discussion forum. In contrast, the average read (number of posts) per learner in the April 2022 semester was only 0.4629, highlighting the impact of the LcL design in promoting increased participation and engagement.

Discussion forum plays a critical role in promoting active learning and collaboration among learners. Through the discussion forum, students have the opportunity to engage in meaningful conversations on module content, share their perspectives and receive feedback from their peers and teachers. The increased participation in the discussion forum is a positive indicator of the effectiveness of the LcL design in promoting active learning and collaboration among students.

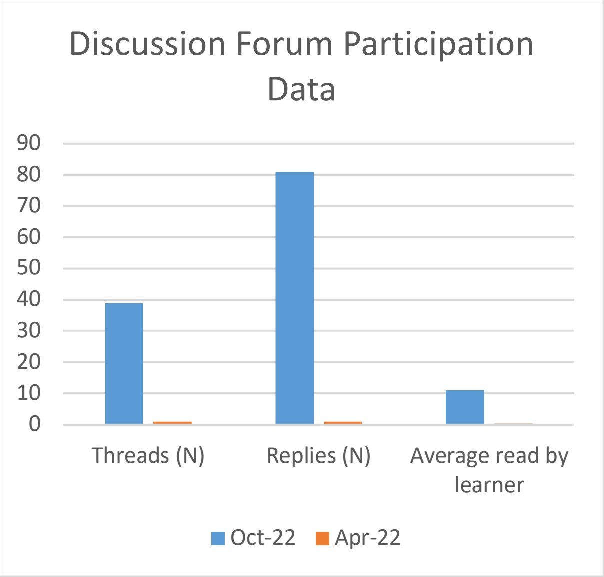

Figure 1 –Discussion Forum Participation Data

Better Performance in Revision Quizzes

Another positive outcome of the LcL design was the improved performance of students in the revision quizzes. The module design included seven revision quizzes, one at the end of each topic, with unlimited attempts. Only the highest attempt was captured, and students were given one semester to work on the quizzes.

Analysis of the results in Table 1 indicated that the performance of students in the revision quizzes was better in the October 2022 semester compared to the April semester 2022. Specifically, the average mark and standard deviation of each revision quiz were better in the October semester compared to its counterpart in the April semester. The improved performance of students in the revision quizzes is a positive outcome of the LcL design. It suggests that the design may have helped students better retain and apply the knowledge they acquired throughout the course.

	Apr 2022 Sem (N=54)		Oct 2022 Sem(N=107)	
	Avg [%]	Std Dev [%]	Avg [%]	Std Dev [%]
Quiz 1	96.98	10.2	98.32	9.22
Quiz 2	97.48	7.04	98.44	6.16
Quiz 3	95.64	13.28	98.48	6.54
Quiz 4	98.08	11.32	99.65	2.81
Quiz 5	96.98	9.43	98.45	7.47
Quiz 6	96.44	11.78	99.35	4.88
Quiz 7	96.86	10.44	99.78	2.19

Table 1 – Performance of Revision Quizzes in Two Semesters

Student's perception of their engagement level with LcL designs in the OAL environment

To gain insights into students' perceptions of their engagement level in the OAL environment which are attributed to the LcL designs, in-class anecdotal feedback was collected from students. Generally, students found the use of badges as a form of reward a positive experience. It was a motivating factor and a source of recognition for their efforts in completing various learning activities, as evident in both the discussion forum participation and the better performance of the revision quizzes.

Another source of evidence is the Student Experience of Teaching (SET) survey. It provided valuable feedback on the effectiveness of LcL designs in promoting student engagement. Some extracted comments are as follow:

"he made brightspace somewhere very interactive and we are able to find solutions and recordings to help us understand in times of uncertainty"

"Mr Soon provides great feedbacks and also conducts consultation every week so that we can understand the topics better"

"Pre-recorded video lectures were very detailed and clear."

The survey showed that learners appreciated the weekly consultation hosted in the Bongo virtual classroom, with recordings made available in the LMS. This provided them with an opportunity to clarify their doubts and interact with their peers and instructors:

Additionally, pre-recorded video lectures were commented positively for its clarity and detail. However, some students also provided feedback that the video duration was a little too long, which may have negatively affected their engagement in the learning process.

It is worth noting that all the class sessions were recorded using Bongo virtual classroom, and the recordings were made available in the LMS. This feature was positively received by students as it allowed them to revisit class sessions at their convenience and their own pace.

Reflections: Impact of Badges & Practicality

The implementation of badges as a form of reward reinforces the LcL design as it showed promising results in terms of improving discussion forum participation and better performance in all seven revision quizzes. Students found the badges to be motivating and a source of recognition for their efforts in the learning process.

However, there is room for further improvement in terms of the practicality of badge usage. While the badges were effective in incentivizing students, more thought needs to be put into exploring additional practical uses of badges to further enhance student engagement. For example, incorporating small gifts or snacks as rewards in exchange for badges could potentially provide additional motivation for students to actively participate in discussions and complete quizzes.

Another dimension to consider is the establishment of a more sophisticated awards system for badges. For instance, implementing different tiers of badges based on different levels of participation in the discussion forum could provide additional incentives for students to actively engage and contribute to the discussions. This could be inspired by platforms like Stack Overflow ("Stack Overflow", n.d.), where users earn different privileges and badges based on their level of participation and contribution.

Reflections: Discussion Forum

The increased participation in the discussion forum is an encouraging sign of engagement among students in the OAL environment. However, a closer inspection reveals that the majority of the replies were posted by teachers, indicating that peer-to-peer collaboration and learning may still be lacking. This highlights the need to further promote and facilitate student-to-student interactions in the discussion forum to foster meaningful peer learning experiences.

During the in-class survey, students expressed concerns about their visible identities in their discussion forum postings. Many students reported feeling hesitant to post or provide feedback for fear of misleading their peers or making mistakes that may be visible to others. This indicates that the current setup of the discussion forum may not be conducive to fostering an open and supportive learning environment.

Therefore, one possible improvement could be to allow students to post anonymously in the discussion forum. This would provide students with a sense of privacy and freedom to express their opinions and ideas without the fear of being judged or identified. This anonymity could potentially encourage more active participation from students, as they may feel more comfortable sharing their thoughts and engaging in discussions.

Furthermore, anonymous posting in the discussion forum could also promote constructive feedback and critical thinking, as students may be more inclined to provide honest feedback and engage in meaningful discussions without the fear of repercussions or embarrassment. This could enhance the quality of peer interactions and promote a supportive and inclusive learning environment where students can learn from one another.

Reflections: Future Enhancements – Byte-Size Content and the Role of Generative AI in the OAL Environment

To effectively engage learners in the OAL environment, careful consideration must be given to the chunking of learning content into manageable, byte-sized pieces for easy consumption. This is supported by findings from the SET survey, which revealed that some students were discouraged by lengthy lecture videos. Besides shortening the videos, another approach to mitigate monotony and promote active engagement is to create interactive videos by incorporating questions, such as multiple-choice or open-ended, within the video. And when students build on the responses of other students, it presents opportunities for social learning, and also the sense of being part of the class and not isolated on their own during the OAL.

Generative artificial intelligence (AI) has emerged as a promising tool with the potential to transform the online learning experience for tertiary students. Leveraging technologies such as natural language processing, machine learning, and deep learning, generative AI has the capability to generate content that can facilitate learning and promote engagement in the online learning environment.

Moving forward, students are encouraged to tap onto the strengths of generative AI in the OAL environment to create personalized learning materials that are tailored to the unique needs and preferences of individual students. For instance, generative AI can generate adaptive learning modules that adjust to the pace and learning style of each student, providing them with a customized learning path. This personalized approach can enhance student engagement and motivation, as students are more likely to be interested and invested in materials that are specifically designed for their individual learning needs. Furthermore, personalized learning materials can foster improved understanding and retention of content, as students can learn at their own pace and receive targeted feedback based on their performance.

Another advantage of generative AI is its potential to facilitate the creation of interactive and immersive learning experiences. For example, generative AI can generate additional sample questions or exercises that offer students extra practice opportunities, reinforcing their understanding of complex concepts and enabling them to apply their knowledge in different contexts. These interactive and immersive learning experiences can enhance student engagement and promote active learning, as students are encouraged to actively participate and apply their knowledge in meaningful ways.

However, it is important to note that the use of generative AI in the OAL environment also presents challenges, particularly in terms of potential bias in the generated content. Generative AI models are trained on large datasets, which may contain biased or incomplete information. As a result, the content generated by these models may unintentionally perpetuate existing biases or misinformation, leading to inaccurate or misleading educational materials. This underscores the importance of thorough review and verification of generated content by educators and institutions to ensure its accuracy, reliability, and fairness.

Conclusions

In this paper, we have examined different LcL designs and evaluated their effectiveness in engaging learners in OAL based on four key principles: learner focus, active learning, collaboration, and feedback/reflection. We found that discussion forums can effectively promote student engagement through peer-to-peer interaction and collaboration, but it is crucial to ensure that discussions are student-led and that students take ownership of their learning. Badges can incentivize student participation and foster a sense of achievement, but their design and implementation must align with the course's learning goals. Further exploration of creative badge usage, such as exchange for small gifts or snacks, can enhance its impact. Byte-sized content with interactivity elements could be introduced to further engage learners. Generative AI has emerged as a promising tool for creating personalized learning materials and facilitating interactive learning experiences, but caution must be exercised to address potential biases and ensure content accuracy, reliability, and fairness.

In conclusion, engaging learners in OAL requires careful consideration of strategies and approaches that promote active participation, meaningful interactions and alignment with learning goals. Discussion forums, badges and generative AI can enhance student engagement and learning outcomes, but thorough planning, implementation, and evaluation are necessary to ensure their effectiveness. By continually refining these strategies, educators can create engaging online learning experiences that promote deep learning and achieve desired learning outcomes.

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ASYNCHRONOUS LECTURES FOR EEE ENGINEERING STUDENTS – WHAT WORKS

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Abstract

This paper presents the implementation of asynchronous lectures in the School of Electrical and Electronic Engineering (SEEE) at Singapore Polytechnic. The COVID-19 pandemic in 2020 has led to a sudden shift from traditional in-person lectures to fully asynchronous online lectures in the school. Guidelines were established for staff in developing such content to ensure consistency in the development, which emphasizes segmenting learning content into bite-sized videos, along with generative activities such as knowledge check questions and Self-Reflective Quizzes. The development of asynchronous lectures adheres to the basic principles of multimedia learning for students. These contents were progressively enhanced with multimedia and interactive elements such as animated graphics and interactive hotspots. However, such enhancements were often resource intensive. Thus, it was necessary to understand how the students perceive the created asynchronous lectures and which aspects they prefer that were beneficial for their learning experience to guide further development. To determine the effectiveness of these lectures and identify areas for improvement, SEEE conducted a survey in May 2022, which received 1214 responses from the students across all three years of the four diplomas in the school. Analysis was performed on the data stratified via the students' preferred mode of lecture delivery. The results of the study revealed that students found generative activities such as knowledge checks questions and Self-Reflective Quizzes beneficial to their learning; they also preferred short videos. Students also expressed the desire for the lecturer's "social presence" in the asynchronous lectures and the importance of having their questions answered during the learning process. The study also looked at the impact of the change in the delivery mode on the student performance. The results suggest improvements in the existing asynchronous lectures and their further developments. The paper offers recommendations for creating engaging asynchronous lectures that meet the needs of the students while considering the limited resources of the school's teaching staff.

Keywords: *e-learning, asynchronous lectures, interactivity, multimedia learning*

Introduction

The COVID-19 pandemic and the imposition of a nationwide partial lockdown in April 2020, known as the 'Circuit Breaker', necessitated full home-based learning for all schools and institutes of higher learning (IHLs) in Singapore. For the School of Electrical and Electronic Engineering (SEEE) at Singapore Polytechnic, it made a complete switch to full flipped learning. This required the conversion of all learning contents previously delivered through face-to-face (F2F) lectures to asynchronous online content using recorded video lectures. Some modules also incorporated interactive multimedia elements to better engage students. All tutorials were conducted as synchronous sessions online until the 'Circuit Breaker' was lifted in early June 2020. Eventually, F2F lectures were replaced across the board by asynchronous lectures in October 2020.

The teaching faculty poured in concerted efforts in the creation of the asynchronous lectures to ensure that student learning was not compromised while studying from home during the initial stage of the pandemic. As part of ongoing continuous improvement, the school had the support of a non-academic development team to work with the module domain specialists to further improve the asynchronous lecture materials since September 2020.

This paper aims to study how the students view the asynchronous lectures created and which aspects of these contents were effective for the students' learning experience. The results obtained would help guide further development in this area.

Development of asynchronous learning contents

In early 2020, the school provided guidelines for teaching staff on the creation of the asynchronous learning content. This is to ensure uniformity and consistent implementation for the more than 100 modules offered by the school. Each topic of a module should have the following:

- Learning Outcomes
- Revision of pre-requisite knowledge (if applicable)
- Lesson materials with "Knowledge Check"

- Illustrative Examples
- Self-Assessment (Self Reflective Quiz)
- Summary
- Further Reading

Lesson materials should be in 5 to 10-minute segments. Non-graded knowledge checks were included so that students could gauge their own understanding of the contents, termed as Self-Reflective Quizzes (SRQs). To ensure that students complete these knowledge checks before the synchronous tutorials, a nominal grade of 5% to 10% was allotted for the SRQs. The SRQs also help teaching staff better monitor student learning and provide just-in-time appropriate learning interventions during the synchronous lessons and/or the practical sessions.

While working from home, the teaching staff employed various means to create the recorded video lectures. The use of voice-over PowerPoint slides was the most common approach due to their familiarity with these. This approach offers increased student engagement and satisfaction during asynchronous online learning (Draus et. al., 2014). However, without access to a recording studio or a quiet space, the audio recordings embedded in the PowerPoint slides came with background noise interferences, such as the occasional dog barking or traffic noise. These required frequent re-recording to minimise such distractions, increasing the time spent on such efforts. A few staff expressed reservations about using their voices as they were uncertain if students would receive their narrations positively. Some staff thus resorted to using text-to-speech narration to read prepared scripts. Nevertheless, all the online learning content created followed the guidelines suggested by the school, as shared earlier.

The use of the recorded video lectures seemed to suggest that the students might be having a passive learning experience with e-learning Level 1 interactivity (Community Team, n.d.). While incorporating the knowledge check and quizzes (SRQs) necessitates students interacting with the e-learning materials to perform in classes, it does little to guide teachers in content creation, especially in improving various aspects of learning materials to better ensure student learning and retention.

The literature suggests that interactivity in multimedia content helps facilitate deep learning by actively engaging the learner in the learning process; students also perceive them to be more enjoyable (Evans & Gibbons, 2007; Ha & Im, 2020). Subsequently, the next stage of development of the asynchronous learning content focused on incorporating e-learning level 2 interactivity such as hotspots, drag and drops, as well as multimedia elements such as animated graphics.

To achieve a higher level of e-learning interactivity in the online learning content, module specialists, with the support of the non-academic development team, worked to improve the multimedia content and added interactivity features. For example, the team edited and removed distracting audio content from the recorded video lectures and voice-over PowerPoint slides for a better student learning experience. Enhancements were made to the graphical contents, including figures, diagrams, flowcharts, and schematics to be of a better quality. Other enhancements to the digital contents also included interactive tabs and other multi-modal displays to capture the attention of students. While incorporating interactive multimedia content was desirable for students to learn engineering modules online, the tasks were often resource intensive. These required iterative steps and close consultation between module specialists and the development team, who were not engineering-trained though versed in media design.

The development of asynchronous lecture contents adheres to the basic principles of multimedia learning for students (Mayer & Fiorella, 2022). Two examples are shared here to illustrate how such multimedia content was done. Example 1 was resource-intensive and required staff well-versed in animation creation, and example 2 involved fewer intensive steps, which might arguably provide a similar student-positive experience.

Example 1: The module specialist narrated a script for a recording, which was then included in a PowerPoint for a voice-over. The voice-over was then aligned to an animated cartoon video created by the support staff using software such as PowToon (voice principle and temporal contiguity principle).

Example 2: The module specialist recorded a lecture on Microsoft Teams. As part of his lecture, he used the laser pointer at appropriate times to build up the explanation of a circuit (signalling principle and voice principle). The media staff then added captions to the video lecture recording (spatial contiguity principle).

To avoid redundancy, key points are emphasized, and simple diagrams are left for students to process themselves. This avoids overloading students with redundancy (redundancy principle).

Incorporating animated cartoon video, as described in example 1 above, required specialized media design knowledge. In comparison, the approach in example 2 could be used for simple concepts and less challenging to adopt and implement by the module specialists.

Method

Given the School-wide implementation of asynchronous lectures in SEEE, it was critical to gather students' views and opinions on these and their preferences for their learning. An email invite containing a video and a survey link was sent to all SEEE students in May 2022. They were asked to watch the video before completing the survey. They were informed about the aims of the study, and participation was voluntary, hence, informed consent could be assumed. Students needed to use their ichat accounts to authenticate their participation. A total of 1214 students participated in the survey.

Design of the survey

This section discusses specific aspects of the survey. It consists of five multiple-choice questions, four opened-ended questions, and one multiple-statement with a 5-point Likert scale, with 1 being "Not at all effective" and 5 being "Extremely effective".

To gather students' preferences on the type of recorded video lectures, a question was included, tethered to the short video on the five prevalent types of recorded video lectures used in SEEE. Figure 1 shows the image as part of the question to ensure the students were clear on these different types.

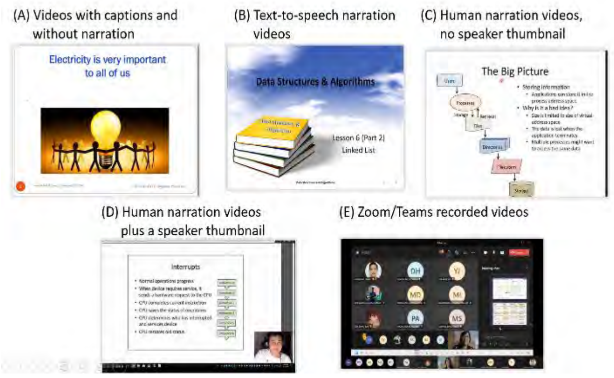

Figure 1. Five Prevalent Types of Videos Produced by Lecturers in Question 5 of the Survey

A similar approach was used for another question to gather their preferences on the types of interactive multimedia content. A short segment of the video illustrates the different types, and an image showing all these types was also included (Figure 2). Examples 1 and 2 discussed earlier are shown to the students as (B) and (C).

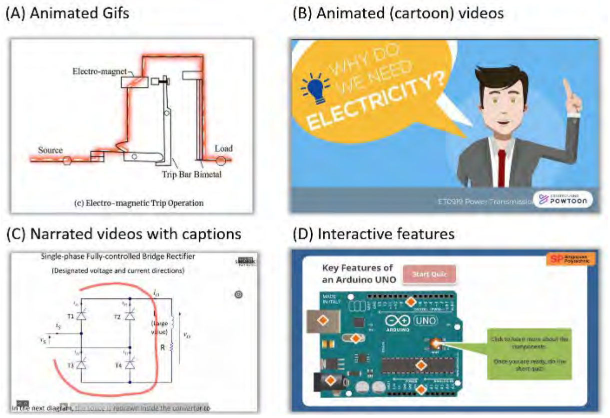

Figure 2. Four Common Types of Interactive Multimedia Content as Part of Question 6 of the Survey

A question on the preferred mode of lecture delivery was included in the survey. By design, to obtain students' true preferred mode of lecture delivery, an option offered was F2F lectures, although these have given way to online asynchronous lectures since April 2020. The aim was to uncover the reasons for such preference, if indicated. The results would be useful to guide on the aspects of F2F lecture that students could have missed because of asynchronous lecture implementation. Such dimensions could be included as a continuous improvement of asynchronous learning content in further development.

The survey also looked at the impact of the change in the delivery mode on the students' performance. The AY2022/2023 Semester One GPA (Grade Point Average) was extracted to examine whether the student's academic performance correlates with the time spent on the asynchronous lectures. The question on the time spent on the asynchronous lectures aims to assess whether students are using the developed contents. This also provides teaching staff the much-needed confidence that the vast amounts of effort required to do a content overhaul was indeed worth their time.

Results

This section discusses the results obtained from the survey.

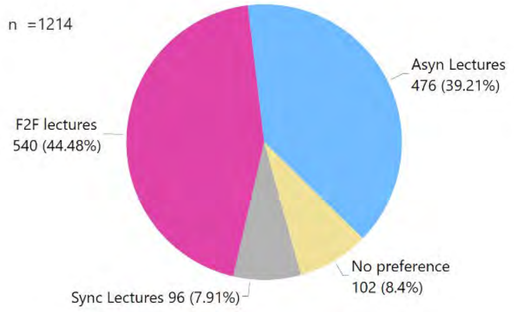

Figure 3. Students' Responses to the Preferred Mode of Lecture Delivery for Question 1

Figure 3 shows that 39.21% of students chose asynchronous lectures, and a slightly higher percentage of 44.48% preferred F2F lectures.

Table 1 shows the top two common reasons for their preferences. Of the students who chose asynchronous lectures, 65.1% gave the reason that they like the flexibility of learning anytime, anywhere and at their own pace, and 21.2% liked the opportunity to review the difficult concepts by watching the videos again. Of the students who chose F2F lectures, 55.2% indicated that they could have their questions addressed by the lecturers during the lectures, and 30.7% thought that they could focus and learn better.

On the preferred type of recorded video lectures (Figure 4), 34.8% of the students preferred the human narration provided by the teaching staff, and 26.5% preferred the human narration of the teaching staff and simultaneously be able to view them in the thumbnail as a part of the recorded lectures. The least preferred type was text-to-speech narrated video lectures, with only 7.1% of the students indicating so. This result aligns with the Social Cues principle in multimedia learning (Mayer & Fiorella, 2022).

Table 1. The top two common reasons given by the students on the Preferred Mode of Delivery

	Number of Students	Percentages in group	Overall percentage
Reasons for choosing asynchronous lectures			
Like learning anytime, anywhere, and own pace	310	65.1%	25.5%
Can review by watching video again	101	21.2%	8.3%
Other reasons	65	13.7%	5.4%
Total	476	100%	39.2%
Reasons for choosing face-to-face Lectures			
Can interact with the instructor and ask questions	298	55.2%	24.5%
Can focus and learn better	166	30.7%	13.7%
Other reasons	76	14.1%	6.3%
Total	540	100%	44.5%

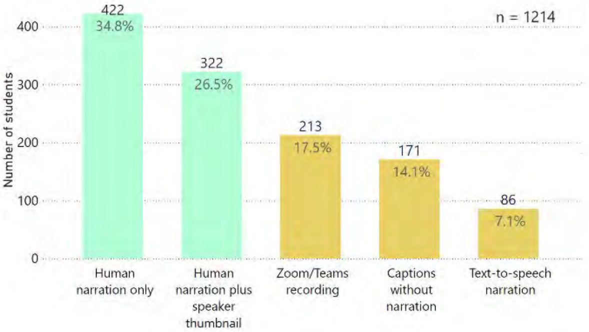

Figure 4. Students' Responses to the Preferred type of Recorded Video Lectures for Question 5

Figure 5 shows the students' responses to the effectiveness of the various elements and features found in interactive multimedia asynchronous content. The chart shows that over 56.0% of the students indicated that all these features were extremely effective or very effective. Narrated videos with captions, mentioned earlier as *example 2*, garnered the highest percentage of 78.5% as extremely effective or very effective. The results assured that the efforts to incorporate interactivity helped increase the effectiveness of the learning content as perceived by students. The students' responses to the effectiveness of bite-sized(short) videos, Graded SRQs, and Non-graded knowledge check questions as extremely effective or very effective in helping them learn were 68.7%, 67.05% and 76.53%, respectively. The percentage obtained was the highest for the non-graded knowledge check questions.

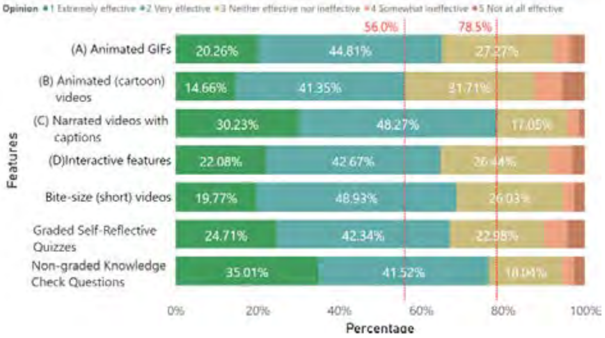

Figure 5. Students' Responses to the Effectiveness of Interactive Multimedia Features, Bite-sized (short) Videos, Graded SRQs and Non-Graded Knowledge Check Questions for Question 6

Figure 6 shows the students' preferences for the type of asynchronous lectures. Most students, 53.05%, preferred a mixture of recorded video lectures and interactive multimedia lectures, and 21.25% of them preferred recorded video lectures. Only 8.65% chose interactive multimedia lectures.

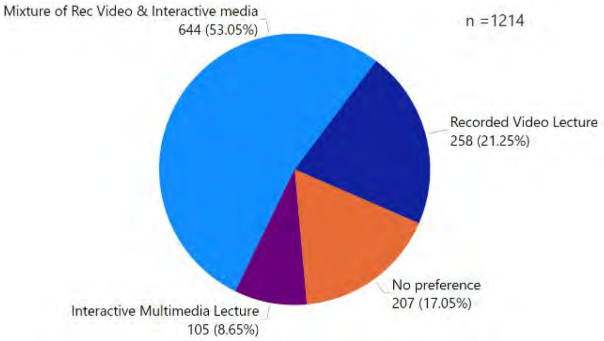

Figure 6. Students' Overall Preference of Asynchronous Lectures for Question 10

Students' responses to what they like and dislike about asynchronous lectures, and suggestions for improvement are shared here. Given the various open-ended responses received, these are broadly categorised with only the top three categories listed here.

The top three likes about asynchronous lectures
- Learning at own pace (55.2%)
- Ability to review content (17.4%)
- Convenience with no need to commute (7.3%)

The top three dislikes about asynchronous lectures
- Inability to pose questions or clear doubts and obtain clarification (27.4%)
- Lack of discipline and lose focus (11.0%)
- Difficulty in following content (6.8%)

The top three suggestions for improvements
- Human voice instead of text-to-speech for narration as it is less monotonous and livelier; teaching staff explain the concepts instead of reading from the slides (14.2%)
- Shorter videos (7.3%)
- Features with appropriate means to enable students to clarify their doubts while learning online (4.1%)

Other interesting suggestions are creating a chatbot to help students clarify their doubts and providing bounded notes bundled with the asynchronous content that requires students to fill in the blanks while learning online.

Figure 7 is a box plot of the AY2022/2023 Semester One GPA of the students and their time spent on a module per week. Eight students have withdrawn from the course. Thus, the total number of students has been reduced to 1206 for this analysis. The result showed that 90.5% of the students spent more than the allotted 1-hour self-directed learning time per module. Further analysis showed that for students who spent 2 to 3 hours or more, their median GPA was 3.27. For those who indicated 4 or more hours, the median was 3.58. Generally, it could be surmised that students spending more time learning the content would obtain better GPA. However, for those who indicated spending less than an hour, their median GPA was higher at 3.31 compared to the median GPA of 3.21 for those who reported time spent of 1 to 2 hours.

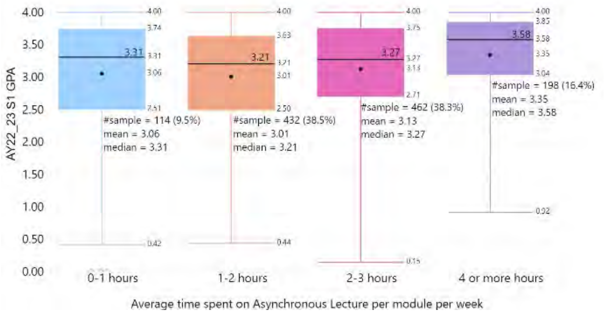

Figure 7. Students' Academic Year 2022/2023 Semester One GPA vs. Time Spent per Module per Week

Discussion and recommendations

The study shows that 67% or more of the students felt that the SRQs, knowledge check, and bite-sized videos, provided in the guidelines to staff for development, were either very effective or extremely effective for learning engineering concepts. Likewise, more than 56% of them indicated the same for interactive features.

The results further showed students' preference (combined percentage of 61.3%) for the presence of the teaching staff as part of the recorded video lectures, with the teaching staff's narration and added presence in the form of a thumbnail to show full body language. This preference aligns with the guiding principles of social cues for multimedia learning referred to earlier, which states that students learn better in an informal style (personalisation principles), preferring human voice (voice principles) and human gestures (embodiment principles).

This is further supported by the theory of "social presence" (Short et al., 1976), which explores the "sense of being with another" in an online environment and how the lecturer's social presence influences the overall student online experience. Students perceive a connection with this social person as being a physical "real" person in an electronic form and view them as social partners. This partnership will motivate the learner to put in more effort to understand what the instructors are saying, which results in better learning outcomes. Having the human aspect in recorded video lectures will also help address one of the top three dislikes of students of asynchronous lectures, that is, the use of computer-generated text-to-speech narration.

The literature cautions that animated and interactive graphics may not improve comprehension compared with their static equivalent (Mayer & Fiorella, 2022). Furthermore, such features should perhaps be included in situations to help novice learners through visualisation and mental representation of the processes. This seems to be reflected in the choice of only 8.65% of the students preferring interactive multimedia lectures for the entire asynchronous learning content.

However, in contrast to what has been offered by the principle of redundancy, that students learn better from graphics and narration than from graphics, narration, and onscreen text, 78.5% of the students rated the narrated video with captions as extremely effective or very effective for learning. A few students further suggested including captions or subtitles in the asynchronous lectures. This could be because engineering terms are not part of everyday spoken English, and so such captions included provide clarity. For instance, terms such as "phase" could be misunderstood as "face", and "source" as "sauce".

Given the demands of extended onscreen time on students, it is not surprising that only 7.91% of students opted for synchronous lectures. While Skylar (2009) suggested that students prefer synchronous lectures using web conferencing tools to text-based lectures, this stood in contrast to another finding that shared increased student burnout and decreased retention during synchronous lessons during the pandemic (Chen et al. ,2020). The school's decision to replace all F2F lectures with asynchronous lectures and retain tutorials in the form of synchronous lessons of twenty students helped minimize the drawbacks of synchronous onscreen time and allowed better monitoring of students to minimize online stress.

Recommendations for improvements in Asynchronous Lectures

Asynchronous lectures provided by the school have the following features:

- Incorporate a lecturer's own narration and/or physical appearance as part of recorded video lectures
- Include captions and sub-titles
- Bite-sized videos
- Presentation should have only key points
- Building of explanation by a lecturer with appropriate on-screen cues

Our findings reaffirm student preferences for the abovementioned features. Thus, it would be prudent to focus on including more of such features in future asynchronous content produced. For example, the students' indicated preferences for recorded video lectures with lecturer's presence and narration (Example 2) is a boon, as this method is less resource intensive.

Teaching staff can record the lecture as though they are teaching on a videoconferencing platform or by using a screen recording software adding personalized prompts in the narration. They then further enhance these by adding captions and further editing if needed.

The school has many highly qualified lecturers with many years of experience teaching engineering, honed through many rounds of explaining, illustrating, and simplifying challenging concepts. Their treasure trove of tacit knowledge can be captured and preserved through the recording of their lectures, in the form of recorded video lectures, which would otherwise be lost either through retirement or resignation.

Future development work for engineering modules can incorporate the above recommendations, in addition to ensuring technical relevance and up-to-date contents. Students' indicated wish for a means of getting their questions addressed while accessing the online content must be further explored to address the students' wishes.

Limitations of the study

Self-reporting is an inherently biased measure of sampling. Pedagogy studies are especially vulnerable to such biases, as what students enjoy may not always correlate with what students benefit the most from. Since the study was concluded in an engineering school, the result may not be generalised across all fields of studies. Finally, surveyed students are not naïve to recorded video lectures and interactive multimedia contents, and their past experiences may have impacted their responses within the survey. Nevertheless, this study, is to the best of our ability, an accurate measure of the two goals this study set out to fulfil.

Conclusion

The COVID-19 crisis has resulted in the replacement of F2F lectures with asynchronous lectures in SEEE. The school has ensured that all modules offered, numbering more than 100, have met minimally, level 1 e-learning interactivity by September 2020. By December 2021, of these, 78 modules were further enhanced to include level 2 e-learning interactivity.

The results show a positive overall acceptance of the asynchronous learning contents created. Most of the students indicated a preference for recorded video lectures mixed with some interactive elements. For the recorded videos, the presence of the teaching staff needs to be enhanced through their own narration and thumbnail for the "social presence" desired by students while accessing the online contents.

Further exploration of the features of the current learning management system, Brightspace, in terms of collaborative tools and discussion board will be needed to address the students' needs for their questions to be addressed while learning online.

The School is progressively improving the quality of the asynchronous lectures based on students' feedback gathered. Further detailed in-depth analysis of students' perceptions, according to the year of studies, will be considered for future work.

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A STUDY OF STUDENT EXPERIENCE IN THE ALeRT PROGRAM AND ITS IMPLICATION FOR LARGE-SCALE IMPLEMENTATION IN SINGAPORE POLYTECHNIC

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Abstract

This paper documents an evaluation of a technology driven framework *ALeRT* (Assessing Learning Regularly for Timely support*)* that incorporated Evidence-based Teaching (EBT) approaches to enhance students' learning when providing timely focused feedback using technology. The aim was the systematic utilization of EdTech tools and data visualization software to enhance specific aspects of the learning process through timely focused feedback. Student performance on learning tasks was captured, analysed, and visually presented in dashboards of the visualization software to display the student learning data in chart form for easy access and immediate action. The overall approach is underpinned by a recognition that good pedagogic design is fundamental to effective learning and must incorporate EBT practices and principles. The methodology followed a broad action research approach incorporating both quantitative and qualitative data on the student learning experience. The primary focus was to better understand and improve key areas of practice; in this case, how an intervention utilizing the ALeRT framework could enhance student assessment and feedback in a timely manner. The findings provided valuable insights into how students experience their learning and identified the most useful (and less useful) aspects of the instructional approach employed. The importance of focused and timely feedback for enhancing learning effectiveness and efficiency was well supported in the data obtained. This included specific evaluation of a range of instructional methods and tools (e.g., quizzes, videos, exit polls) on their specific impact in the feedback process.

Keywords: *Evidence-Based Teaching; Assessment; Feedback; EdTech*

Introduction & Aim

This paper documents an evaluation of a technology driven framework *ALeRT* (Assessing Learning Regularly for Timely support*)* that incorporated Evidence-based Teaching (EBT) approaches to enhance students' learning when providing timely focused feedback using Learning Management System (LMS) with third-party software. Data from Microsoft Forms (pre-class quiz result and exit poll result) were merged with LMS's data (graded quiz result) using Robotic Process Automation (RPA) and Power BI to display the student's correlation data in chart forms.

ALeRT was implemented in 2021/2022 Semester 2, with two modules, Digital Electronics 1 and Digital Electronics 2, and involved 47 classes, encompassing 874 students and 22 teaching staff. The specific research questions include:

- How useful did students find the EdTech tools employed (e.g., online quizzes, exit poll) in providing effective feedback to support their learning?
- What aspects of the instructional approach were perceived as most (and least) useful by students?
- How might the overall instructional approach, including specific features, be improved future programmes.

Singapore Polytechnic (SP) Education Model

SP seeks to provide a holistic education for its students, with the aim of developing students who are able to become Self-Directed Learners. (SDL). The key competence underpinning SDL is the capability to be metacognitive. As Noushad (2008) concluded:

> "…metacognitive strategies are essential for the twenty-first century because they will enable students to successfully cope with new situations and the challenges of lifelong learning" (p.16).

There is a clear recognition that any technological innovation must be underpinned by sound instructional design principles, based on the most current research on how students learn and what instructional methods work best. There is now a more scientific approach to understanding learning and teaching, increasingly referred to as Evidence-based Teaching (EBT). This is the result of our enhanced knowledge relating to how humans learn, what teaching methods and practices work best and why (e.g., Marzano, 2007; 2010; Hattie, 2009, and Petty, 2009).

There is debate in the literature about the relative affordances and limitations of online learning as compared to traditional face-to-face learning. However, Horton (2006) puts this discussion in its most useful context:

"At its best, e-learning is as good as the best classroom learning. At its worst, it is as bad as the worst classroom learning. The difference is design" (p.3).

Furthermore, as Moroder (2013) discovered from her experience:

"Technology does not make learning more engaging or meaningful. A great lesson does this…technology can make it more effective and efficient."

In summary, ALeRT aims to utilize the affordance of EdTech with our increasing understanding of human learning to make instruction more effective, efficient and engaging.

The Impact of Feedback on Student Learning

The benefit of being able to assess student learning regularly is that it enables teaching faculty to gain immediate insight into what students understand or do not understand, provide them with the most useful feedback, and then facilitate the necessary remediation in the most effective and efficient ways. Research has consistently shown that quality feedback is a key strategy for educational attainment. For example, the extensive meta-analysis of research on the effectiveness of different teaching methods by Hattie (2009) recorded an average Effect Size of 0.73 for feedback (i.e., students getting feedback on their work from the teacher, peers, self, or others).

There are many interrelated aspects that contribute to the high impact potential of feedback on learning. Nicol & MacFarlane-Dick (2006) in synthesizing the research literature suggest the following seven principles of good feedback practice:

1. helps clarify what good performance is (goals, criteria, expected standards)
2. facilitates the development of self-assessment (reflection) in learning.
3. delivers high-quality information to students about their learning.
4. encourages teacher and peer dialogue around learning.
5. encourages positive motivational beliefs and self-esteem.
6. provides opportunities to close the gap between current and desired performance.
7. provides information to teachers that can be used to shape teaching (p.203)

Approach & Methodology

The research was designed to capture specific aspects of the learning experience of first year Digital Electronics students during the project intervention duration. The methodology involved collecting quantitative and qualitative data through a questionnaire, comprising fixed and open response items tailored to the research goal and key questions. (*The questionnaire items are contained in Appendix A*).

It follows the broad aims of action research (AR), which primarily seeks to better understand and improve practice – in this case how an intervention utilizing EdTech tools could enhance student assessment in a timely manner. While AR may not generate highly generalizable findings through extensive experimental surveys, it does as Stringer (2004) noted:

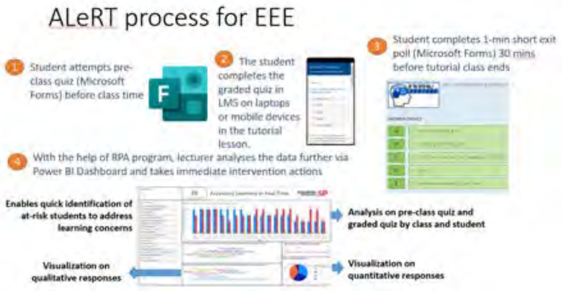
"encapsulate the systematic qualitative research routines now becoming commonplace in the educational arena and increasingly applied by teachers and administrators as part of their work in schools" (p.6).

The ALeRT implementation involved the following activity stages:

1. Students are informed to study a specific topic at home and prepare for a pre-class quiz (readiness test).
2. One day before the two-hour-long tutorial lesson, the teaching faculty will email or WhatsApp an MS Form URL link to students informing them to complete the pre-class quiz before they attend the tutorial lesson. (Note: This way, teaching faculty would already know the student's pre-class performance through the responses from Microsoft Form and be aware of who the 'at-risk' students are.)
3. During the face-to-face tutorial lesson, the teaching faculty will go through the pre-class quiz with the whole class and help students to reinforce what has been learned and fill in knowledge gaps where necessary.
4. The teaching faculty will then introduce more challenging problems for students to work on collaboratively and solve. In situ, short, focused instruction is provided as needed, and student questions are addressed.
5. Thirty minutes before the end of the lesson, the teaching faculty will conduct a supervised 10-minute graded quiz in LMS to gauge students understanding in class.
6. After the students complete the graded quiz, they will do a one-minute short exit poll to tell the teaching faculty which topic of the 1.5-hour tutorial they still had difficulty with. The exit poll is completed using Microsoft Form.

7. The teaching faculty will display the results of the pre-class quiz, graded quiz and feedback from the exit poll via the Power-Bi dashboard. The teaching faculty will then analyse the data further to see whether students still have learning gaps or misconceptions, and then use the remaining time of the tutorial to address these.
8. After the lesson, the teaching faculty upload the weekly MS Form Excel file and graded quiz Excel file to OneDrive for the record.

This process is summarized and the key pedagogic activities are highlighted in figures 1 & 2 below.


ALeRT process for EEE

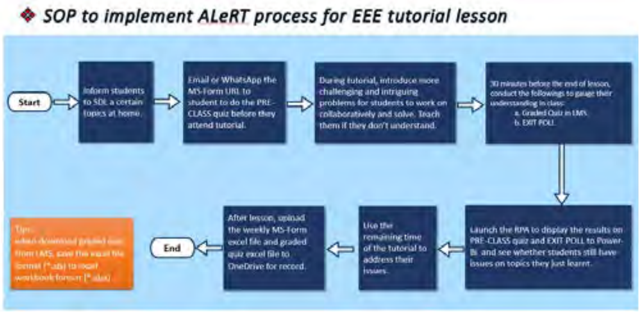
1 Student attempts pre-class quiz (Microsoft Forms) before class time

2 The student completes the graded quiz in LMS on laptops or mobile devices in the tutorial lesson.

3 Student completes 1-min short exit poll (Microsoft Forms) 30 mins before tutorial class ends

4 With the help of RPA program, lecturer analyses the data further via Power BI Dashboard and takes immediate intervention actions

Figure 1. ALeRT Process by EEE


SOP to implement ALeRT process for EEE tutorial lesson

Inform students to SDL a certain topics at home.

Email or WhatsApp the MS-Form URL to student to do the PRE-CLASS quiz before they attend tutorial.

During tutorial, introduce more challenging and intriguing problems for students to work on collaboratively and solve. Teach them if they don't understand.

30 minutes before the end of lesson, conduct the followings to gauge their understanding in class:
a. Graded Quiz in LMS
b. EXIT POLL

Launch the RPA to display the results on PRE-CLASS quiz and EXIT POLL to Power-Bi and see whether students still have issues on topics they just learnt.

Use the remaining time of the tutorial to address their issues.

After lesson, upload the weekly MS-Form excel file and graded quiz excel file to OneDrive for record.

Tips:
when download graded quiz from LMS, save the excel file format (*.xls) to excel workbook format (*.xlsx)

Figure 2. SOP to apply ALeRT for EEE tutorial lesson

Quantitative analysis was employed in the collation of students' responses as well as direct quotes from the open-response items, in which the actual words/phrases are used to highlight key aspects of their experience (e.g., Corbin & Strauss, 2008).

Results & Analysis

The summary data from the fixed response items in the questionnaire are presented below (Figures 3 to 5).

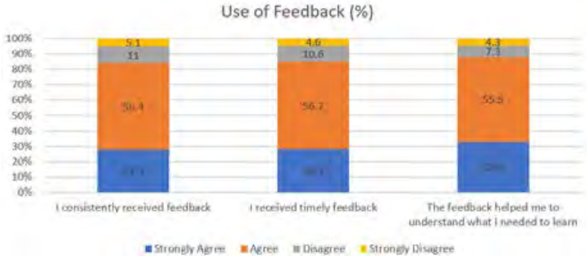


Figure 3. Questions on the use of feedback in ALeRT

The data relating to student perceptions of the feedback received (e.g., consistent and timely), as well as its usefulness in helping them to understand the content is positive, with 83.9%, 84.8% and 88.4% responding in the combined 'Agree' and 'Strongly agree' response options.

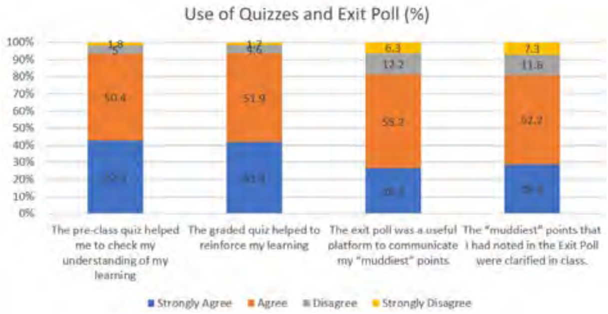


Figure 4. Questions on the use of quizzes and exit poll in ALeRT

The responses to the use of both the pre-class and graded quizzes are both positive (with 93.2% responding in the combined 'Agree' and 'Strongly agree' response options) and exceptionally similar. The student's perception of the use of the exit poll is positive but the percentages of 'Strongly agree' responses are notably lower than that accorded to the quizzes.

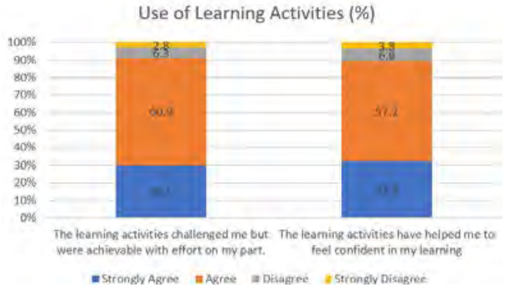


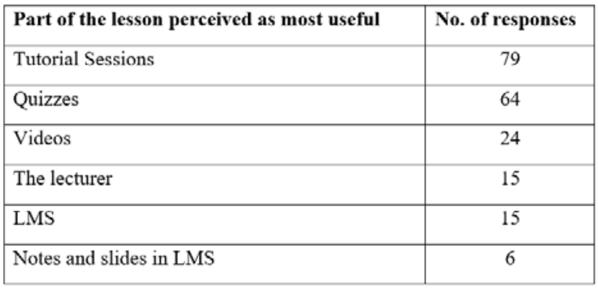
Figure 5. Questions on the use of learning activities in ALeRT

The learning activities employed in the initiative received positive responses, with 90.9% and 89.4% respectively, responding to the combined 'Agree' and 'Strongly agree' response options. The data from the open response items identify the most useful and least useful features in this initiative, as well as areas for improvements in future practice. Tables 1 & 2 summarize the areas perceived as most and least useful.

79 students highlighted tutorial sessions as the most useful part of the lessons. In the fixed response items on learning activities, 89.4% to 90.9% of the students agreed that the learning activities in class (tutorials) challenged them and helped them to feel confident in their learning. The tutorial sessions were able to support the learning from the pre-class quiz as they enabled the opportunity to get the additional knowledge needed, interact with the

lecturer and peers, and engage in questioning and other learning activities to obtain more detailed feedback and build understanding.

Table 1: Summary of students' responses to the most useful parts of the lessons



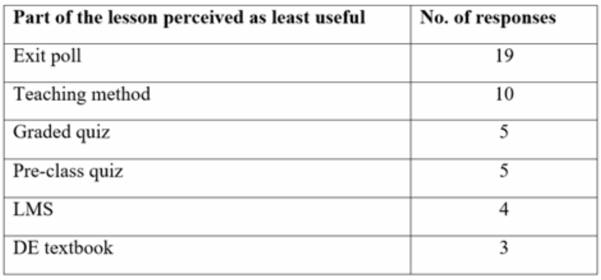
Part of the lesson perceived as most useful	No. of responses
Tutorial Sessions	79
Quizzes	64
Videos	24
The lecturer	15
LMS	15
Notes and slides in LMS	6

The quizzes (highlighted by 64 students) were seen as being useful in enabling students to get the essential feedback on what they knew, did not know and what further learning was required. This was also reflected in the fixed response items on quizzes with over 93% of the students agreeing that quizzes helped to check their understanding and reinforced their learning.

The videos were also well received (highlighted by 24 students), especially when they were short and focused on the key learning concepts. This has implications for the design and creation of self-directed learning materials.

15 students highlighted the lecturer as the most useful part of the lessons. Research has suggested that teacher quality is an important factor that influences student achievement (Hattie, 2003; Petty, 2009). As in all teaching context, where the lecturer is seen as competent and easy to communicate with, student learning is enhanced.

Table 2: Summary of students' responses to the least useful parts of the lessons



Part of the lesson perceived as least useful	No. of responses
Exit poll	19
Teaching method	10
Graded quiz	5
Pre-class quiz	5
LMS	4
DE textbook	3

The exit poll scored highest in terms of the least useful aspect (though this only represents 4.8% of the student responders). These students did not see this as necessary as their questions were usually dealt with in class, and others felt it did not add anything to their learning. One made the comment of 'Doing it for the sake of it.' This may explain the notably lower percentages of 'Strongly agree' responses on the use of the exit poll than that accorded to the quizzes. For future ALeRT implementation, better integration of exit poll with learning activities needs to be implemented.

Of note, some students identified their lecturer as the most useful aspect of their lessons (as identified in Table 1), but there were others who clearly did not. This may reflect in part students preferred teaching styles, but may also be a lack of competency in certain areas by some lecturers. There were also 5 students who referred to 'everything' as being less useful, with some making comments such as 'Lecturer didn't teach us in the tutorials; hard to understand; dry and boring'.

While many students (64 students and over 93% in fixed response items) highlighted the usefulness of quizzes, the main concern was insufficient time allowed for completion as gathered from the students' responses to the least useful parts of the lessons. Together with the exit poll findings, this reinforces the importance of using an EBT approach in designing instructional strategies and maximizing the affordances of technology interventions.

Comments relating to the DE textbook referred to it being complicated and hard to understand, and LMS having too much information and being very wordy. These responses, together with the responses about the usefulness of short and focused videos, emphasized the design considerations for self-directed learning materials.

Implications for Practice

The results from this research initiative offer practical insights into how best to utilize Edtech tools to maximize student feedback and support the wider learning process. These are summarized in the following subsections:

1. Applying EBT in planning and evaluating instruction

The findings reinforce the importance of using an EBT approach to maximize the affordances of technology interventions. While the increasing range and capability of technology platforms and Edtech tools are enabling both the diagnosis of student learning in a timely manner, it is essential that such use is underpinned by sound pedagogic design principles. For example, quizzes, when well-constructed and calibrated to the learning outcomes, are effective instructional activities for assessing prior learning and facilitating the necessary retrieval practice to build knowledge and understanding in long-term memory.

However, as with all effective methods, they need to be well designed and facilitated, as well as not over-used. Based on those responses that mentioned quizzes as a less useful part of the lesson, the reasons given were too many quizzes and the graded quiz not resulting in feedback, which is a major reason for quizzes being an effective learning tool. The key implication is to ensure that quizzes are fully aligned to key concepts relating to the learning outcomes, and not just a standard '5 quizzes every segment', also, as outlined in the literature review, providing feedback that focuses on the specific area(s) of learning deficit is most important.

Tutorials are a structure in which a range of effective instruction methods can be combined and blended, what Hattie (2009) referred to as 'Russian Dolls'. These include explanations of key concepts, questioning, the use of activities, examples, and analogies, as well as utilizing positive features of teacher-student relationships. This method combination when facilitated effectively encourages students' engagement and thinking (e.g., analysis, comparison & contrast, inference and interpretations, and evaluation), which is essential to building deep understanding. It also facilitates intrinsic motivation (e.g., Ryan & Deci, 2008; Reeve, 2015).

2. Diagnosing learning gaps and personalization of instruction

The capability to identify specific student learning gaps and being able to provide focused intervention strategies are essential aspects of effective instruction and well documented in the literature (e.g., Hattie, 2009). This research has demonstrated how technology affordances can increase the effectiveness and efficiency of providing the necessary feedback and remediation needed for a wider range of student learning needs. This enables faculty to quickly identify weaker potentially at-risk failure students and provide the necessary learning support.

Refining and extending the blending of effective instructional methods, using an EBT approach and methods with emerging technologies such as learning analytics and user-friendly Edtech tools will constitute a key aspect of the future of learning in the coming years. It is highly likely that the use of videos, especially interactive videos with quizzes that provide timely feedback, will become an essential feature of instruction, especially in the context of the ongoing shift towards more blended and fully online learning.

Apart from the pedagogic benefits, such technology blending is becoming increasingly cost-effective, especially with free or low-cost user-friendly Edtech (e.g., Quizzes, Kahoot, Socrative). Hence, ALeRT is highly scalable across the SP curriculum.

3. Enhancing teacher expertise through professional development

As ALeRT is an important educational thrust in SP, there is a need to upscale professional learning to the wider institutional context, developing what Hargreaves and Fullan (2012) refer to as 'Professional Capital' (i.e., institution-wide faculty expertise). From the conflicting feedback on the effectiveness of lecturers, it may reflect the different competence levels of lecturers. Petty (2009) fully contextualized the importance of good teachers in real-life terms when he wrote:

"Good teachers touch people's lives forever. If you teach well, some of your students will only succeed because of your excellent teaching. They then might go on to get more advanced qualifications and skills, again just because of your expert teaching. Then they might get a career, indeed a whole life, built on your excellent teaching. No other profession is that consequential and enabling."

It is therefore essential to provide the necessary professional development to ensure that all lecturers are able to design and facilitate this pedagogic initiative from an EBT approach. However, the kinds of professional development activities that are effective require considerable resource time and effort, which may not be congruent with present practice in many educational institutions. For example, Gulamhussein (2013) emphasized:

"The duration of professional development must be significant and ongoing to allow time for teachers to learn a new strategy and grapple with the implementation problem" (p.3).

At present, SP is developing what Hargreaves and Fullan (2012) refer to as 'Human Capital' (i.e., individual faculty achieving high expertise), and there has been sharing of learning through staff development briefings and workshops. Hence, we are seeking to achieve what Hargreaves and Fullan describe as 'Social Capital' (i.e., increasing numbers of faculty sharing their work and learning experiences).

For the future, we need to continue building on the social capital presently being developed, to foster a learning community committed to achieving sufficient Professional Capital for the longer-term educational goal of building a unified pedagogic and EdTech approach to learning and teaching – irrespective of delivery mode.

Summary

This paper has outlined a pedagogic intervention, initiated in response to the challenge of providing effective and efficient online learning during the Covid-19 pandemic, and now extended to further utilize the affordances of Edtech in providing effective feedback regularly in the learning process. The research findings suggest that, when used from an EBT approach, it can play a significant role in enhancing student learning outcomes. This work is now being extended towards establishing a framework for data-enabled flipped learning.

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Appendix A: Questionnaire items

1. I consistently received feedback.
2. I received timely feedback,
3. The feedback helped me to understand what I needed to learn.
4. The pre-class quiz helped me to check my understanding of my learning.
5. The graded quiz helped to reinforce my learning.
6. The exit poll was a useful platform to communicate my “muddiest” points (things I did not fully understand).
7. The “muddiest” points that I had noted in the Exit Poll were clarified in class.
8. The learning activities challenged me, but were achievable with effort on my part.
9. The learning activities have helped me to feel confident in my learning.
10. Which part(s) of the lessons were the most useful in helping your learning, and why?
11. Which part(s) of the lessons were less useful to your learning, and why?
12. Please offer your suggestions on how we might make the learning experience more effective/interesting to help you learn better in the future.

REMOTE LABS FOR LIFELONG LEARNING: ENGAGING STUDENTS WITH ACTIVE LEARNING PEDAGOGY

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Abstract

COVID-19 pandemic has brought uncertainty in educational responses, skilling methods and training practices across institutions. Remote Lab, which provides online interfaces to physical labs, allows students to conduct experiments with real-world equipment anywhere, anytime. Furthermore, the interactive e-Learning package helps institutions guarantee the continuity of students' learning processes, regardless the obstacles faced. Therefore, Remote Lab and e-Learning packages were integrated as teaching platforms to seamlessly achieve the learning objectives. Given the pandemic's multiple restrictions on lab hours - a significant hindrance to students' learning - these platforms are especially useful. This paper summarises the approach and outcomes of Remote Lab and the implementation of an interactive e-Learning package for a lab-based Industrial IoT Analytics module. Moreover, it outlines the rationale for implementing Remote Lab, with the goals of lifelong learning and employing active learning pedagogical framework. It shares a full instructional strategy, demonstrating how high-effect teaching methods, calibrated to cognitive scientific principles, were combined with appropriate educational technology tools to create effective learning experiences.

The 2020–2021 academic year was unique for educators, who adapted to conduct courses remotely. Due to strict protocols, students returned home immediately after lessons. To prevent students' learning from being unduly compromised, the author set-up a Remote Lab, developed an engaging, interactive e-Learning package with formative assessments, and implemented them. Despite the shift back to face-to-face teaching post-COVID-19, the online resources remain accessible by Pre-Employment Training (PET) and Continuing Education and Training (CET) students in the Learning Management System (LMS). Remote Lab provided students with real-time, industrial hands-on experience to access shop floor machines in the SMART industry platform virtually. Allowing CET students to access these resources promotes lifelong learning and continual upskilling to meet current industrial needs, thereby broadening career prospects. This also promotes inclusivity, as all students can virtually access resources remotely. The resources are well-received by students, primarily because the Remote Lab is more accessible, and students can rewatch the e-Learning modules multiple times, hence facilitating self-directed learning. Based on the findings, both resources are recommended to be adopted post-pandemic, to aid students' lifelong and active learning, long-term knowledge retention and upskilling.

Keywords: *remote lab, active, lifelong, interactive, e-Learning*

Introduction

Polytechnics in Singapore are tertiary institutions that adopt a Practice-based and Skills Education (PSE) framework to prepare learners for and upskill learners in the working world, alongside aiming to nurture graduates to be lifelong learners. The emphasis within polytechnic education is geared towards preparing PET students to be ready for the workforce, and guiding CET students to upskill, keep abreast of emerging demands and thereby stay relevant in the new economy. Education statistics digest (2022) reports that around 46% of students from post-secondary education enrol into polytechnic, a significant proportion of individuals.

In Temasek Polytechnic, Industrial Internet of Things Analytics is offered as an elective module to four PET diploma courses in the third year of students' polytechnic diploma study, and as a core module to two CET diploma courses in the second year of their polytechnic diploma study in the School of Engineering. Due to COVID-19, which led to the institution of strict protocols and restricted stay on campus, the teaching team adopted a Remote Lab integrated with an interactive e-Learning package to ensure that students could have an unduly compromised learning experience. After the shift back to face-to-face teaching post-COVID-19, both resources were made available round the clock. This facilitated and fulfilled interested students' intellectual curiosity, as they could continue to access the machines remotely and learn at their own pace, fostering long-term skill retention. The increased accessibility of resources also created a more inclusive learning environment, as disabled students, or students who, for other reasons, must take courses remotely could continue learning (Colwell, Scanton, & Cooper, 2022; Scanlon, Colwell, Cooper, & Di Paolo, 2004). The pilot phase of the Remote Lab with e-Learning package was started at the end of April 2021 semester and has had three consecutive runs. This is a step towards 'student-centric' pedagogy, where the student takes control of their learning pace and therefore develops lifelong learning skills. In line with this, the pilot run was found to promote one-to-one technology-enhanced learning, which enabled "seamless learning spaces", active learning, increased students' engagement, long-term retention, lifelong learning and upskilling to meet current industrial needs. Bhute et al., 2021; Zubia & Alves, 2011 reports that Remote Labs provide online interfaces for physical labs. In traditional practical lessons, the facilitator explains the objective of the lesson and introduces the shop floor machines and software needed for the experiment. Additionally, the facilitator shows the experimental setup and explains the procedure to connect, extract and analyse the sensor data using suitable software. After the experiment has been completed, the results of the experiment have to be validated by the lab facilitator. As students need to return home immediately after lab lessons during COVID-19, apart from verbal explanations and demonstrations, students are also given access to Remote Lab, integrated with e-Learning modules, to practise at their own pace for long-term retention. Access to the e-Learning module is given in LMS at the beginning of the semester, which has details of the experiment, equipment needed, experimental set-up and the procedure to complete the experiment. The Remote Lab can be accessed by students for experimentation through a web-based interface. Research shows that students' learning outcomes in Remote Labs are equal or better compared to physical labs (Brinson, 2015; Corter et al., 2011; heradio et al., 2016; Post et al., 2019). Felder, R.M., & Silverman, L.K. (1988) divide learners into five major groups based on their learning preferences. Figure 1 shows the suitability of Remote Lab integrated with an interactive e-Learning module for learners with different learning styles.

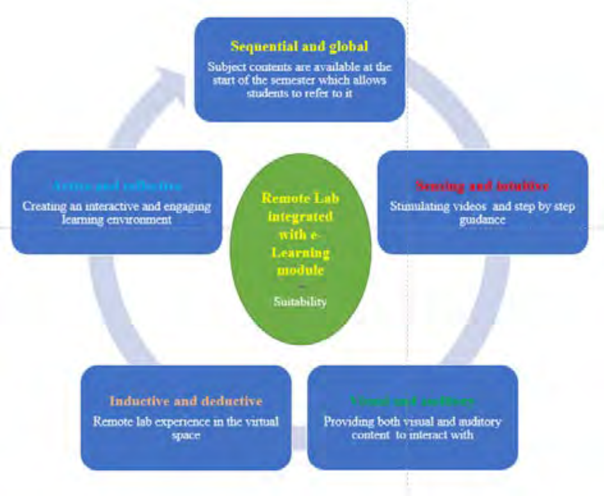


Figure 1: Learning Styles

Active learning is built on formative assessment with reflection, feedback, and support, rather than on summative assessment (Cattaneo, 2017). Formative assessment is therefore incorporated in the e-Learning module and their performance is captured in LMS for teachers, as feedback on students' learning.

In this paper, the author discusses the use of the Remote Lab integrated with interactive e-Learning modules for facilitating practical sessions that helps students retain information and upskill themselves. The author will also discuss the development of the learning resources, feedback gathered, and impact of the resources on students' performance.

Subject Delivery

A lab-based practical approach was used in a third year, first semester elective subject called Industrial IoT Analytics. Students were enrolled for this subject in a 16-week semester. This subject covers essential concepts, the application of industrial software platforms to wirelessly interconnect sensors and the development of dashboards for acquiring, analysing and displaying data commonly found in Industry 4.0 digital transformation. Students were split into small groups of 25 and were scheduled for 4-hour weekly lab sessions. Students were expected to do a pre-reading of the lab sheets uploaded in the LMS and come prepared for the practical lesson. During the practical lesson, under the guidance of a lab facilitator, students will follow the instructions in the lab sheets and complete the lab procedures. At the end of each topic, the facilitator played a Kahoot game to recap the lesson content. Using apps and games for learning assessment create an engaging, interactive learning environment, driven by healthy competition. This is a powerful new strategy to influence and motivate groups of people, including students. (Gamification. 2013). In summary, the practical lesson plan was designed with appropriate teaching activities and was delivered using suitable teaching tools to effectively facilitate student learning. After gathering students' feedback, the teaching activities and the application of the teaching tools were reviewed, adapted and modified to suit their learning needs.

Remote Lab integrated with an interactive e-Learning module

Industrial IoT Analytics is one of the modules offered to PET and CET students, where students typically have no prior hands-on experience in handling Industrial 4.0 use cases and the relevant software. During COVID-19, students needed to conduct experiments with guidance from the lab facilitator, and immediately leave the campus after lessons. The subsequent lack of on-campus practice due to pandemic restrictions led to the development of additional online learning resources, such as Remote Lab–to access shop floor machines virtually–and interactive e-Learning modules with formative assessments–for active learning. As the Remote Lab setup and procedures to access the shop floor machines were new and unfamiliar to students, the e-Learning module actively engaged them with an enhanced guided visual procedure to sustain their interest and attention. The implementation of these appropriate learning resources helped students gain more hands-on practice. A major advantage of Remote Lab, unlike traditional learning methods, is that the former is far more accessible. Moreover, the Remote Lab not only challenged students intellectually, but also did so in an engaging, easily comprehensible manner. Another advantage of Remote Lab is that students are expected and required to display self-regulation by planning and executing experiments themselves (Daradoumis, Marques Puig, Arguedas, Calvet Linan, 2021; cf., Litzinger, lattuca, Hadgraft, Newsletter, 2011). Nonetheless, conducting Remote Lab experiments online comes at the cost of teachers and peers being physically present to encourage, motivate and support them during experiments. However, the e-Learning module makes up for the lack of teachers. As students have hands-on experience once in the lab, guided by lab facilitators, additional resources and facilities help them to continue learning outside the lab at their own pace. It also promotes lifelong learning and upskills CET students. The students, who could access the additional resources post-Covid-19, mentioned benefitting from the resources in the ways detailed above.

Development of the e-Learning module and Remote Lab

Students who use both synchronous and asynchronous methods are achieving better grades in contrast to a traditional learning style (Alzahrani, 2019). Current LMS support the usage of completely encapsulated online courses and assessments, using vehicles like the SCORM standard. Hence, all the experiments with audio guided visual procedure are integrated with interactivity and formative assessments using articulate 360. It is developed as a SCORM package and made available to students in the LMS platform. This pedagogy offers a unique sense of presence of teachers and interactivity which are not achieved with the other traditional methods. Students used these additional resources to practise and attempt formative assessments for the preparation of continual assessments and projects. LMS provides a system training platform that holds e-Learning classes to track course completion and assessment scores (Jung & Huh, 2019; Watson & Watson, 2012). Hence, tutors are able to track students' practice sessions using Learning Analytics, which helps to identify, monitor, intervene and aid low attainers.

Figure 2 shows the development cycle of the interactive e-Learning SCORM package for active learning pedagogy.

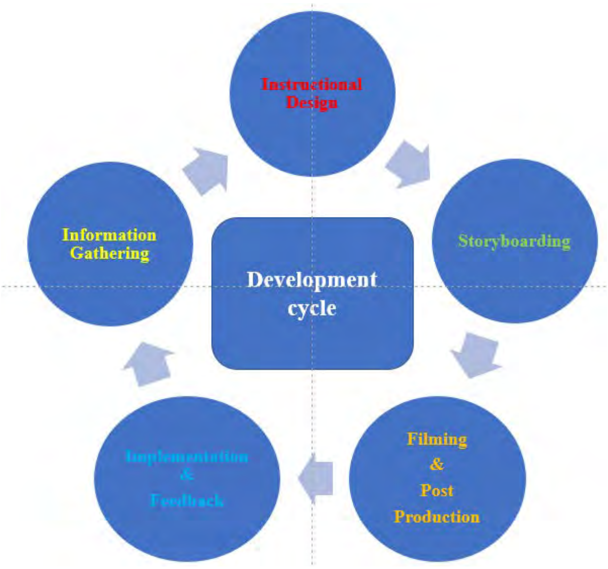
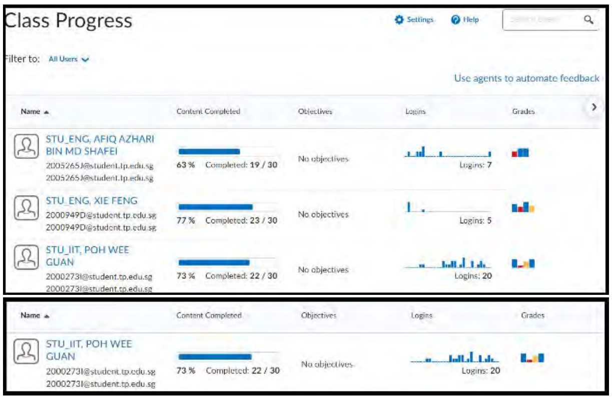


Figure 2: Development Cycle

Figure 3 shows the tracking of students' practice sessions using LMS platform and their performance in the formative assessment.



Class Progress

Filter to: All Users

Use agents to automate feedback

Name	Content Completed	Objectives	Logins	Grades
STU_ENG, AFIQ AZHARI BIN MD SHAFEI 2005265J@student.tp.edu.sg 2005265J@student.tp.edu.sg	63 % Completed: 19 / 30	No objectives	Logins: 7	
STU_ENG, XIE FENG 2000949D@student.tp.edu.sg 2000949D@student.tp.edu.sg	77 % Completed: 23 / 30	No objectives	Logins: 5	
STU_IIT, POH WEE GUAN 2000273I@student.tp.edu.sg 2000273I@student.tp.edu.sg	73 % Completed: 22 / 30	No objectives	Logins: 20	

Name	Content Completed	Objectives	Logins	Grades
STU_IIT, POH WEE GUAN 2000273I@student.tp.edu.sg 2000273I@student.tp.edu.sg	73 % Completed: 22 / 30	No objectives	Logins: 20	

Figure 3: Learning Analytics

To access the shop floor machines from anywhere and at any time due to COVID-19 restrictions, it was decided that Remote Lab would be developed to support the students to practise the procedures. A Remote Lab includes a physical experiment set-up, a user tracking system, a repository of information for students and staff, and a user-interface. The Remote Lab used in this study was designed to be scalable in the number of physical set-ups, students and courses, and was allowed for individual assignments. The Remote Lab could be accessed by students for experimentation through a web-based interface. Students could reserve time slots on a 24/7 basis. Figure 4 shows the Remote Lab set-up of the shop floor machines and students' access to it.

Figure 4: Remote Lab Set-up

Scenario 1: Face-to-Face Lab

During the COVID-19 pandemic, both PET and CET students needed to conduct experiments, but were required to leave the campus immediately after lessons. Hence, they lacked sufficient practice for their continual assessments and projects. To be better prepared for such situations, a scenario in Remote Lab, with interactive e-Learning SCORM package for active learning, was introduced. Students were expected to do a pre-reading of the lab sheets available in LMS, watch the e-Learning modules and complete the formative assessment to review their understanding of the concepts and procedures. During the face-to-face lab session, students applied their knowledge, and conducted the experiments in the presence of lab facilitators.

Scenario 2: Remote Lab

Students became familiarised with the hardware set-up during the face-to-face lab sessions. To receive more practice, students are allowed to access the shop floor machines from anywhere, at any time. They can also conduct the experiment by watching the e-Learning modules, which have audio and visual step-by-step guidance and explanations recorded. They can rewatch them if necessary, at their own pace, to improve their understanding. CET students and students from the workforce are given access to Remote Lab and LMS platform for the whole semester to upskill themselves progressively, which contributes to their lifelong learning. During post-COVID-19, the teaching team enabled students to continue accessing the Remote Lab and e-Learning module in the LMS platform to view and practise at their own convenience. Figure 5 shows the real time data acquisition of the sensors in the shop floor machine via Remote Lab.

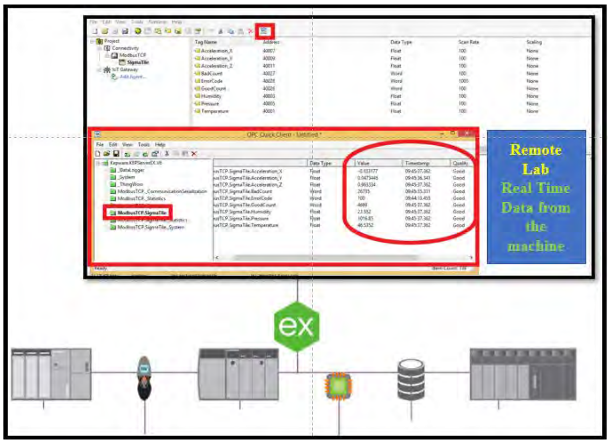


Figure 5: Real time data acquisition

Figure 6 shows the real time monitoring of the sensors' data in the shop floor machine via Remote Lab.

Figure 6: Real time data monitoring

Figure 7 shows the SCORM package for guided audio and visual procedure of the Remote Lab with formative assessment.

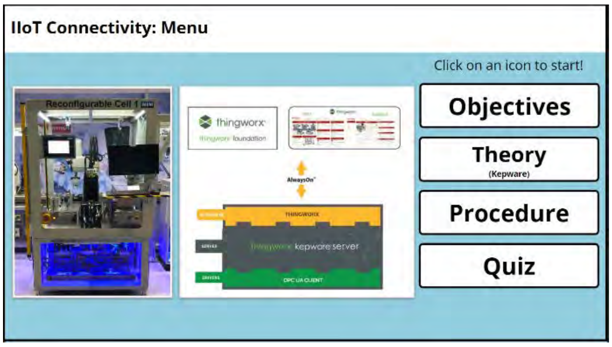


Figure 7: SCORM package

Figure 8 shows the formative assessment, which was integrated with audio visual procedure using Articulate 360 and subsequently developed as SCORM package.

ThingWorx
IIoT Connectivity Quiz

Figure 8: Formative Assessment

Results and Discussion

Remote Lab with e-Learning modules was made available to students from term 2 of the April 2021 semester, and since then, more than 300 students have been given access to these resources. Due to the guided and interactive nature of these online modules, students were motivated to incorporate these resources into their learning, reviews and reflections. Furthermore, students used these resources for pre-practical readings, ensuring that they were well-prepared for the actual session. The resource, which has audio and visual guidance, also served as a very useful tool for students to repeat the Remote Lab experiments, review the lab procedures independently by rewatching them, revise for their projects and practise prior to their practical test. During the practical session, students were expected to complete the tasks, as stated in the lab sheet, and the lab tutor then checked their results and provided relevant, individualised feedback. Lab participation marks were awarded to students based on:

1. Efforts: Manages time well; well prepared before lessons and complies with all lab rules
2. Skills: Demonstrates excellent lab skills, shows great confidence in using software and hardware

Students' lab participation performance before and after the introduction of the e-Lab SCORM package was studied. Based on tutors' observation, the percentage of students with poor performance who raised their hands for help during practical lessons had dropped in the April 2022 semester. This meant that more students were better prepared for the sessions. Evidently, besides in-person guidance offered by the lab facilitator, the Remote Lab with cloud version software and SCORM package, both aided slower learners, as well as high achievers, to better understand the lab procedures, complete them at their own pace and review again. It promoted independent, active and lifelong learning amongst students.

Two practical tests are conducted at a regular interval to assess students' practical skills. For the April 2021 semester, the online resources were made available for reference while doing the project. A comparison of students' performance in the practical test over the two years (April 2021 and April 2022) was carried out. After the introduction of the Remote Lab and SCORM package, there was a significant drop in the percentage of failures for the practical test. This illustrates that students were able to better learn, retain and apply their knowledge during the practical test. Hence, there was also a significant increase in the average marks of students after the introduction of online learning resources in the April 2022 semester.

As part of the subject review, a survey was conducted to gather feedback on the subject delivery, which included the rolling-out of Remote Lab and SCORM package. Separate surveys with the same questions were released to PET and CET students. Figures 9 and 10 show the bar chart for the PET and CET students' response corresponding to the survey results.

Q1: I preferred the remote-access lab experiment to the in-person lab experiment.
Q2: I was able to do at my own pace and repeat procedures that I did not understand.
Q3: Performing Remote Access Lab helped me to develop practical hands-on skills at my own pace.

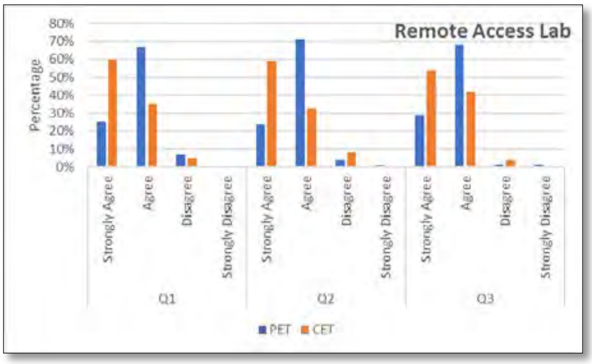


Figure 9: Survey results

From the survey results, a majority of students preferred the Remote Access Lab to the in-person lab and felt positively about being able to do the Remote Lab and repeat the procedures at their own pace. It helped to develop hands-on skills and subsequently complete the experiment. This shows that active, lifelong learning has effectively taken place among and benefitted students.

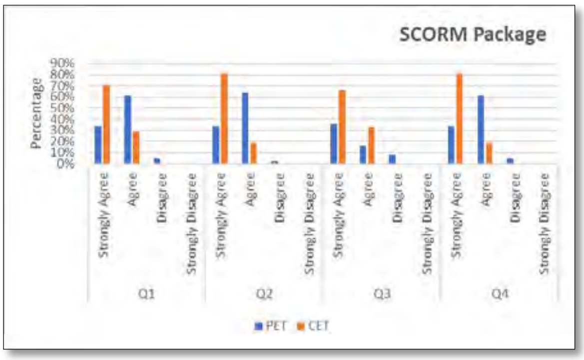


Figure 10: Survey results

Q1: The e-Lab video gave me more confidence in my ability to do labs.
Q2: I was able to learn at do at my own pace and review portions that I did not understand.
Q3: The e-Lab video is engaging.
Q4: The quizzes at the end of each e-Lab video helped me to check the understanding of the concepts.

From the survey results, a majority of students felt more confident in their ability to do the labs and felt positively about being able to review the labs and rewatch it at their own pace. Moreover, most found the resource engaging and agreed that it helped to assess their understanding of the concepts. This shows that the interactive resource was well-received by the students, promoted long-term knowledge retention, self-directed learning and deepened the students' understanding.

Conclusion

Remote Lab integrated with an interactive SCORM package was developed and made available to all PET and CET students in the cohort, both during and after the Covid-19 pandemic. The effectiveness of these resources in enhancing students' learning was studied by analysing students' feedback, which was gathered from student satisfaction surveys. Due to the convenience, interactivity, and step-by-step visual and audio guidance in the resources, students felt incentivised to utilise them while learning. Furthermore, students actively engaged themselves during the experiment because of the variation in the guidance procedure offered. Almost all students agreed that the resources had helped them understand the experimental procedures, retain their knowledge, and cultivate the habits of active, lifelong learning and upskilling. They also felt that they had gained sufficient practice to perform well for their assessments and projects. The drop in percentage of failures in both the practical test and lab participation illustrates that both resources have helped low attainers learn more effectively and apply their knowledge to excel in assessments. In summary, the access to Remote Lab and e-lab SCORM package post-COVID-19 have resulted in the following notable benefits:

1. Promoting active learning amongst students via e-lab SCORM package
2. Facilitating efficient learning, via interactions with and access to the shop floor machines
3. Upskilling for CET students
4. Lifelong learning for CET students
5. A student-centric approach, which encourages self-directed learning
6. Building a learning environment inclusive of learners' different styles, via a variety of available resources

In conclusion, the implementation of Remote Lab with interactive SCORM package post-COVID-19, especially for subjects requiring expensive equipment, was a success. It was effective in enhancing students' active learning, evidenced from students' improved performance in assessments and overall positive feedback.

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Educational Practice of Finite Element Methods in National Institute of Technology

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Abstract

CAE analysis software is widely used among engineers. However, because the mathematical theory used in CAE analysis is treated as a black box, there have been cases where CAE analysis is not used correctly. CAE analysis software is also used in graduation research and special activities at National institute of technology (KOSEN), but since the mathematical theory of CAE analysis is not included in the model core curriculum of KOSEN, there is a problem that students cannot understand the mechanism of CAE analysis even if they are taught how to use the software. If you want to learn the mathematical principles, the educational materials for engineers often focus on calculation methods, and the part about mathematical principles is not described in detail. On the other hand, educational materials for mathematicians often have a style of rigorously building up theories, which can be difficult for engineers to approach.

In order to improve engineering technology in Japan, practical education that interpolates engineering and pure mathematics is considered necessary in future educational courses. Therefore, we are currently conducting a course to understand the mathematical theory of the finite element method, which is the basis of CAE analysis, as part of the advancement of technical college education. The course is implemented by means of online lectures and online learning materials for students belonging to five technical colleges: Suzuka College, Sasebo College, Nara College, Kurume College, and Oita College. To interpolate engineering and pure mathematics, we adapt the method of "learning calculation methods while clarifying what is black boxed" and then "understanding the mathematical theory that was black boxed" in this education.

In this study, we discuss educational contents and effects of the "understanding the mathematical theory that was a black box" part.

Keywords: *CAE analysis, Finite element method, Differential equation, Galerkin method, KOSEN*

Introduction

The Finite Element Method (FEM) is a numerical technique used to find approximate solutions for differential equations. This method is employed in CAE analysis and widely used among engineers. However, the mathematical principles underlying this method are often treated as a black box, leading to instances where experimental results do not coincide with those obtained through CAE analysis. When we teach CAE analysis to students for their graduation research topics, only a few students have an inherent understanding of how the accuracy of the approximate solution can be improved by properly cutting the mesh and adjusting the number of meshes. Hence it is desirable that the education for Finite Element method is taught in National Institute of Technology (KOSEN).

In order to deal with Finite Element Method in KOSEN, we have to teach mathematical contents not included in the model core curriculum. Many engineering textbooks for the finite element method are written with basic linear algebra (matrix calculations) as prerequisite knowledge. However, to understand the mathematical principles of the finite element method, basic linear algebra alone is not sufficient. Since the computation itself is possible as long as basic linear algebra are understood, many students are still doing the computation without a good understanding of the principles. Thus, we adapt the method of "learning calculation methods while clarifying what is black boxed" and then "understanding the mathematical theory that was black boxed" in this education.

In this study, we discuss educational contents and effects of the "understanding the mathematical theory that was a black box" part.

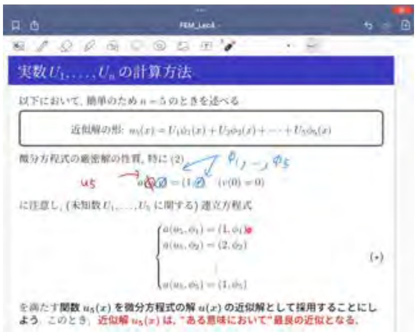
Materials and Methods or pedagogy

We give online lectures and online learning materials for students belonging to five National Institute of Technology: Suzuka College, Sasebo College, Nara College, Kurume College, and Oita College. The contents of lectures are as follows:

1. What is "Finite Element Method"?

2. Calculations by Finite Element Method and Black box points (1)
3. Calculations by Finite Element Method and Black box points (2)
4. Summary of Calculations by Finite Element Method and Black box points
5. Linear algebra (1): Matrix and its properties
6. Linear algebra (2): Linear spaces
7. Galerkin method (1-1): The existence of approximate solution
8. Galerkin method (1-2): The existence of approximate solution
9. Galerkin method (2-1): Error estimate for approximate solution
10. Galerkin method (2-2): Error estimate for approximate solution
11. Error Estimate for the approximate solution calculated by Finite Element Method.

In the curriculum of KOSEN, the students only learn the differential equations having explicitly computable solution. They do not learn the existence and uniqueness of solutions for differential equations in detail. Hence, in the lectures, we started to teach the difficulty of solving differential equations and usefulness of approximate solutions to motivate the finite element method. The contents from Lecture 1 to 4 are from motivation to calculation method of finite element method. These lectures have been conducted and the results were presented at National Convention record I.E.E. Japan (2023). Figure 1 is an atmosphere of an online lecture.



実数 $U_1,\ldots,U_n$ の計算方法

以下において，簡単のため $n=5$ のときを述べる

近似解の形: $u_5(x)=U_1\phi_1(x)+U_2\phi_2(x)+\cdots+U_5\phi_5(x)$

微分方程式の厳密解の性質，特に (2)

u_5 $\longrightarrow$ $a(u,\phi)=(1,\phi)$ $(v(0)=0)$

$\phi_1,\ldots,\phi_5$

に注意し，(未知数 $U_1,\ldots,U_5$ に関する) 連立方程式

$$\begin{cases} a(u_5,\phi_1)=(1,\phi_1) \\ a(u_5,\phi_2)=(2,\phi_2) \\ \vdots \\ a(u_5,\phi_5)=(1,\phi_5) \end{cases} \qquad (*)$$

を満たす関数 $u_5(x)$ を微分方程式の解 $u(x)$ の近似解として採用することにしよう．このとき，近似解 $u_5(x)$ は，"ある意味において"最良の近似となる．

Figure1. An atmosphere of an online

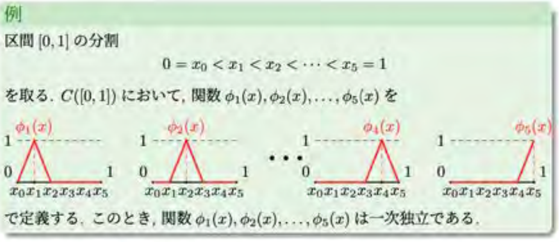
The main contents of this article are the following:

1. The existence of approximate solution
2. Error estimate for approximate solution

1. The existence of approximate solution

The educational materials for engineers often focus on calculation methods, and the part about mathematical principles is not described in detail. In the previous lectures, we clarified a black box part and teach how to calculate approximate solutions for differential equations only. Why the approximate solutions exist have been treated as a block box.

To explain the existence of approximate solution, we need to teach linear algebra and a part of functional analysis. In model core curriculum in KOSEN (2023), although matrix calculations and the linear transformation of coordinates were included, the linear spaces did not include. Hence, we added linear algebra to lectures. Figure 2 is a part of the lectures. Functional analysis is a generalization of linear algebra. Finite Element Method needs the theory of Sobolev spaces which is a part of functional analysis. Although we explain the details about the mathematical principles, we taught in a way that didn't contradict intuition while utilizing knowledge of linear spaces. Moreover, we need matrix calculations to get the approximate solution. In this lecture, we could show students how matrix calculations they learned in KOSEN are helpful. We compare the approximate solution obtained by Finite Element Method with the exact solution visually (see Figure 3).


例

区間 [0, 1] の分割

$$0=x_0<x_1<x_2<\cdots<x_5=1$$

を取る．$C([0,1])$ において，関数 $\phi_1(x),\phi_2(x),\ldots,\phi_5(x)$ を

で定義する．このとき，関数 $\phi_1(x),\phi_2(x),\ldots,\phi_5(x)$ は一次独立である．

Figure 2. Lecture for linear spaces

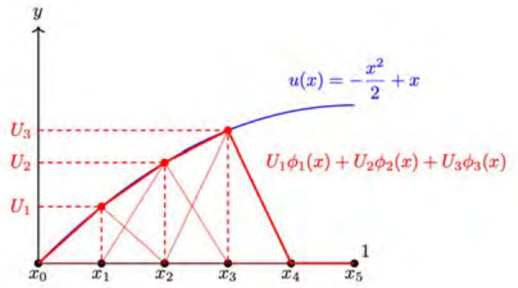


Figure 3. the approximate solution and the exact solution

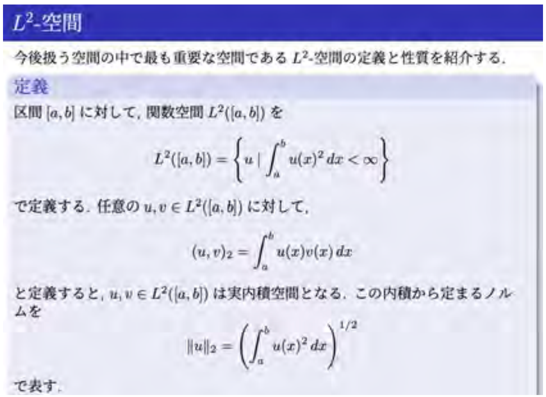
2. Error estimate for approximate solution

The accuracy of the approximate solution obtained by Finite Element Method is the most important part for engineers. To improve skills for CAE analysis, we had better understand the following:

2-1. What criterion or measure is used to determine how well the approximate solution approximates the exact solution?
2-2. How close is the approximate solution to the exact solution?
2-3. The relation between the approximate solution and meshes.

2-1. What criterion or measure is used to determine how well the approximate solution approximates the exact solution?

In mathematics, there exists the concept of "norm". This is a tool to introduce "distance" for vector spaces. In this lecture, we introduced "L^2-norm" (see Figure 4) which is one of the most important mathematical concepts in function spaces. Moreover, we explained that L^2-norm is used to measure the proximity between approximate solutions and exact solutions. In the definition of L^2-norm, we use the integral. The integral can represent the size of objects, such as "length" and "area". By emphasizing this fact, we tried to help students understand more deeply.



L^2-空間

今後扱う空間の中で最も重要な空間である L^2-空間の定義と性質を紹介する.

定義

区間 $[a,b]$ に対して, 関数空間 $L^2([a,b])$ を

$$L^2([a,b]) = \left\{ u \mid \int_a^b u(x)^2\,dx < \infty \right\}$$

で定義する. 任意の $u, v \in L^2([a,b])$ に対して,

$$(u,v)_2 = \int_a^b u(x)v(x)\,dx$$

と定義すると, $u, v \in L^2([a,b])$ は実内積空間となる. この内積から定まるノルムを

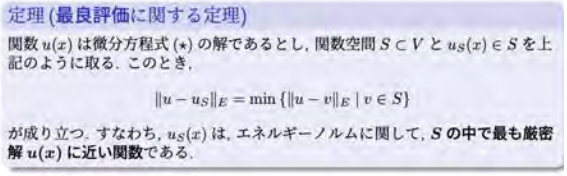
$$\|u\|_2 = \left(\int_a^b u(x)^2\,dx \right)^{1/2}$$

で表す.

Figure 4. Definition of L^2-norm

2-2. How close is the approximate solution to the exact solution?

In the section 2-1, we introduce "L^2-norm" which is a distance in function spaces. Taking the difference between approximate solutions and exact solutions in the sense of L^2-norm, we get error terms. This error term has a parameter that is determined by the mesh generation and the number of meshes. To get this error term, we introduced a new norm "energy norm" which is similar to L^2-norm. We showed the approximate solution obtained by Finite Element Method is the closest solution to the exact solution in the sense of energy norm (see Figure 5).



定理 (最良評価に関する定理)

関数 $u(x)$ は微分方程式 $(\star)$ の解であるとし, 関数空間 $S \subset V$ と $u_S(x) \in S$ を上記のように取る. このとき,

$$\|u - u_S\|_E = \min\{\|u - v\|_E \mid v \in S\}$$

が成り立つ. すなわち, $u_S(x)$ は, エネルギーノルムに関して, **S の中で最も厳密解 $u(x)$ に近い関数**である.

Figure 5. Lecture for the Error Estimate

2-3. The relation between the approximate solution and meshes.

The more the number of meshes increase, the better the accuracy of the approximate solution is. We used SageMath, a free and open-source mathematics software, to create educational materials that enable users to dynamically observe how the accuracy of the approximate solution improves based on the mesh generation and the number of meshes. We show an example of dynamical materials in Figure 6. In Figure 6, we also find that Finite Element Method can only be applied locally.

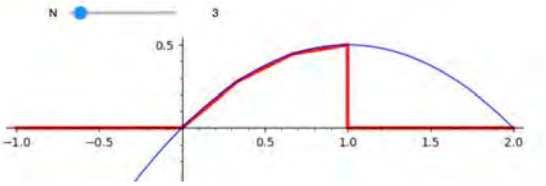


Figure 6. Dynamically materials by Sagemath

Results and Discussion

Certain educational effects were obtained for understanding the mathematical principle of Finite Element Method. Many students found it difficult to accept the peculiar and technical language used in mathematics. This is a point that should be corrected in the future. We have not been able to provide hands-on training in CAE analysis, so we would like to work on this in our future educational activities.

Conclusions

We were able to carry out educational activities that had never been done at KOSEN before. We consider that in the near future, we can incorporate this into the classes.

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A Step-by-Step Education Program of Radio-Frequency Impedance Matching in Electrical Engineering

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Abstract

Impedance matching in electrical engineering is a very important concept for radio-frequency electrical circuit design. Electrical circuits without impedance matching are not power efficient and do not lead effective telecommunication. Incomplete impedance matching may cause breakdown or fire by power reflection. However, impedance matching is difficult to learn because it requires deep understanding of both the electrical circuit and electromagnetism. Here we present a step-by-step education program of impedance matching performed in National Institute of Technology, Ariake College (Ariake Kosen). This education program is ranged over three grades in the Kosen system so that students learn it without difficulty. The program comprises four practices. The education starts in the fourth grade from electromagnetism theory with Maxwell's equations including the skin effect and electromagnetic wave. Actual impedance matching of an audio circuit in the KHz region is performed in the next fifth grade. Finally, in the sixth grade (first grade of the advanced course), impedance matching of the circuit in the MHz region and that of a waveguide in the GHz region are experienced with the S-parameter analysis using a vector network analyzer (VNA). The VNA is one of the most expensive apparatuses in electrical engineering. Fortunately, a low-cost VNA such as NanoVNA is released recently. Through this program, Kosen students will be expected as radio-frequency electrical engineers.

Keywords: *Impedance matching, audio circuit, waveguide, S-parameters, vector network analyzer (VNA)*

Introduction

A voltage signal is a kind of electromagnetic wave. The wave is characterized by wavelength λ, expressed by $\lambda = {}^{c}/_{f}$ [m], where f is the frequency $[\mathrm{Hz} = {}^{1}/_{\mathrm{s}}]$ and c is the speed of light, $299{,}792{,}458\ {}^{\mathrm{m}}/_{\mathrm{s}}$ in vacuum. The wavelengths of commercial 50/60 Hz voltages are calculated as approximately 6000/5000 km. In general, people do not feel the influence of the wavelengths of voltage signals on electrical circuits.

On the other hand, the characteristics of an electrical circuit working at a radio frequency depend on its size. The wavelength of a 2.45-GHz signal, a frequency for the wireless local area network (LAN) and microwave ovens, is calculated as only 122 mm that is comparable to the actual circuit size. Figure 1 shows variation of voltage signals that are expressed by $A = A_0 \exp(j\omega t)$, where ω is angular frequency, on a 30-mm distance line without any elements on the circuit. Signals of 50/60 Hz keep constant anywhere on the line. However, another signal at a frequency of 2.45 GHz varies. Even if 0 V at the point X, the maximum signal is observed at the point Y that is ${}^{1}/_{4}\,\lambda$ apart from X. An invisible passive element must be considered.

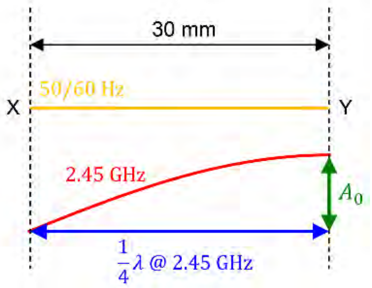

Figure 1. Voltage variation in a 30-mm distance line without any elements between X and Y. 50/60-Hz or low-frequency signals do not vary on the line; however, because the distance matches ${}^{1}/_{4}\,\lambda$ of a 2.45-GHz signal, the maximum value A_0 is observed at the point Y.

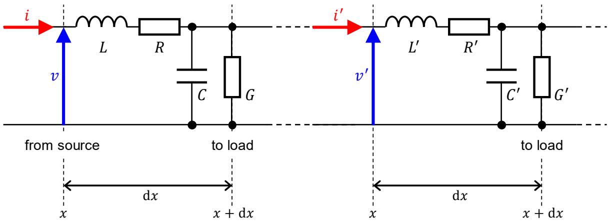

Figure 2. Sequential connection of DCCs.

When designing a radio-frequency circuit, the distributed constant circuit (DCC) analysis must be considered, instead of the lumped constant circuit (LCC) analysis that expresses a general electrical circuit. Figure 2 shows that a DCC is composed of a series of an inductor L, a resistor R, a parallel of a capacitor C, and another resistor G. The voltage and current are both a function of distance x. An actual radio-frequency circuit is regarded as sequential connection of DCCs.

A DCC is analyzed by the following telegraph equations (Equations 1 and 2) on voltage v and current i,

$$\begin{cases} -\dfrac{\mathrm{d}v}{\mathrm{d}x} = (j\omega L + R)i = Zi, & (1) \\ -\dfrac{\mathrm{d}i}{\mathrm{d}x} = (j\omega C + G)v = Yv, & (2) \end{cases}$$

where $Z \equiv j\omega L + R$ and $Y \equiv j\omega C + G$. From these equations, we obtain the voltage and current results (Equations 3 and 4),

$$\therefore \begin{cases} v = \begin{Bmatrix} A\exp\left(-j\omega\sqrt{LC}x\right) \\ +B\exp\left(j\omega\sqrt{LC}x\right) \end{Bmatrix} \exp(j\omega t), & (3) \\ i = \begin{Bmatrix} A\sqrt{\dfrac{C}{L}}\exp\left(-j\omega\sqrt{LC}x\right) \\ -B\sqrt{\dfrac{C}{L}}\exp\left(j\omega\sqrt{LC}x\right) \end{Bmatrix} \exp(j\omega t), & (4) \end{cases}$$

where A and B are constants. We can easily understand that the voltage in a DCC is composed of two members: the first one expresses the travelling wave $V_{\mathrm{f}} = A\exp\left(-j\omega\sqrt{LC}x\right)\exp(j\omega t)$ that goes forward; the second one expresses the reflected wave $V_{\mathrm{r}} = B\exp\left(j\omega\sqrt{LC}x\right)\exp(j\omega t)$ that reflects back. The current is composed similarly. The reflected wave tells us that the input voltage is reflected and back to the source, resulting in $v \neq v'$ (see Fig. 2). It also means that the power/signal transfer is inefficient and the source may be destroyed.

Let us consider an actual DCC with the whole impedance Z_0, as shown in Figure 3. The whole length is ℓ. R and G are omitted for simplicity. The input connects with a power source having a voltage v_{p} and an input impedance Z_{p}. The output connects with a load having an impedance Z_ℓ. The voltage reflection coefficient Γ is expressed by

$$|\Gamma| \equiv \frac{V_{\mathrm{r}}}{V_{\mathrm{f}}} = \left|\frac{Z_\ell - Z_0}{Z_\ell + Z_0}\right|. \qquad (5)$$

Equation 5 demonstrates that if the $|\Gamma|$ value becomes zero, no reflection is accomplished. In other words, every DCC impedance comprising a whole radio-frequency circuit must be the same. That is the *impedance matching*.

However, impedance matching is difficult to learn because it requires deep understanding of both electrical circuit and electromagnetism. Here we propose a step-by-step education program comprising four practices so that students learn it without difficulty. This program is ranged over three grades in the Kosen system.

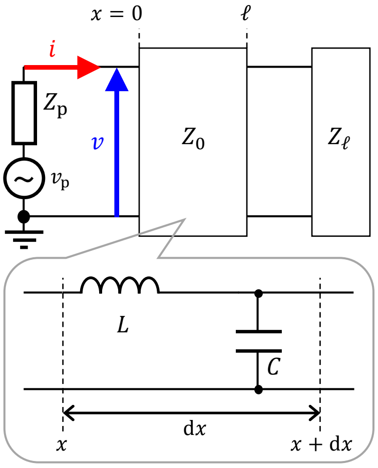

Figure 3. An actual DCC. The whole impedance Z_0, and the length is ℓ. R and G are omitted for simplicity. The input connects with a couple of power source with a voltage v_{p} and input impedance Z_{p}. The output connects with a load having an impedance Z_ℓ.

Practices 1&2: Electromagnetic Wave Theory and Audio Impedance Matching in KHz Region

First of all, in a half of the fourth grade, we educate students to electromagnetism with Maxwell's equations, which unifies electric, magnetic, and light. They learn the skin effect and electromagnetic wave. They learn that an AC voltage can be treated as a wave having a certain wavelength.

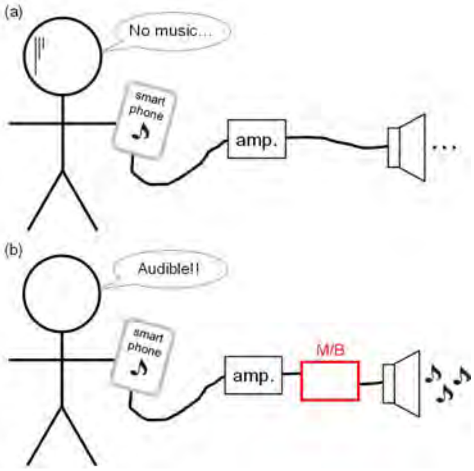

Figure 4. Music from a smart phone played through a speaker: (a) without and (b) with a M/B.

Based on this electromagnetism theory, in a quarter of the next fifth grade, we educate students to a familiar impedance matching example, an audio circuit. We can listen to any music from a smart phone. To open the music for everyone, we may connect an amplifier and a speaker to the smart phone; however, we hear the music very small or cannot as a result, as shown in Figure 4(a), because the output impedance of the smart phone or amplifier and that of the speaker are unmatched.

Thus, as shown in Figure 4(b), by inserting an impedance matching box (matching box, M/B) to the line, everyone can listen to the music. The M/B adjusts different impedances between connected components so that the reflected wave set to zero, explained later. However, in actual audio systems, several transformers instead of a M/B are used. This is because the audible range is very wide from 20 to 20,000 Hz, in contrast, the M/B can adjust impedance at only one frequency. Small impedance mismatching with a transformer at some frequency is adjusted by an equalizer.

These phenomena are electrically explained how efficiently we transfer power. Figure 5 shows an electrical circuit with a power source with a voltage V_0 and an output impedance $Z_0 = R_0 + jX_0$ and a load with an impedance $Z' = R' + jX'$. We need to make the power for the load P' the maximum.

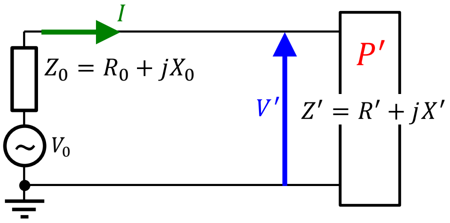

Figure 5. An electrical circuit to explain maximizing power supply to a load.

The complex power for the load P_c' is expressed by

$$P_c' = V'\bar{I} = \frac{Z'}{Z_0 + Z'} V_0 \cdot \overline{\frac{V_0}{Z_0 + Z'}}. \tag{6}$$

Thus, P' is obtained by

$$\therefore P' = \mathrm{Re}(P_c') = \frac{R'}{(R_0 + R')^2 + (X_0 + X')^2} {V_0}^2. \tag{7}$$

The P' takes its maximum when ${}^{\partial P'}/_{\partial R'} = {}^{\partial P'}/_{\partial X'} = 0$. A couple of $R' = R_0$ and $X' = -X_0$ satisfy the condition, leading $Z' = \overline{Z_0}$. Figure 6 shows the $P' - R'$ curve. The P' goes to the maximum 50% at $R' = R_0$. Especially, when $R' < R_0$, the value becomes smaller steeply. Thus, impedance matching is more important in this area. Because the output impedance of power sources is generally $R_0 = 50\ \Omega$, and that of actual speakers is $R' = 8\ \Omega$ or much less than $50\ \Omega$, the above matching condition is critical.

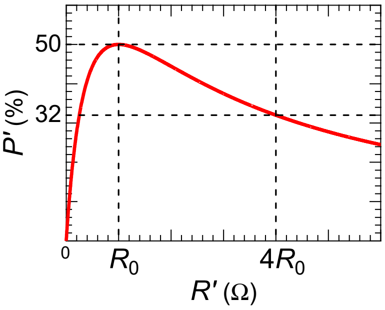

Figure 6. $P' - R'$ curve for impedance matching.

Figure 7 shows an electrical circuit with a M/B. The M/B comprises an inductor (coil) L and two variable capacitors, C_1 and C_2. The former capacitor set parallel to the load is called a load capacitor, and the latter series is a phase capacitor.

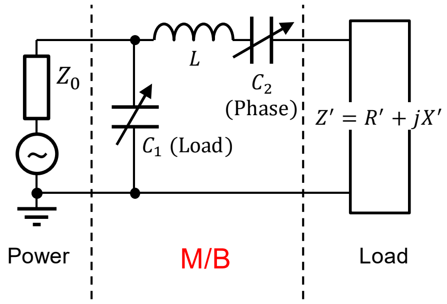

Figure 7. An electrical circuit with a M/B.

The values of these passive elements are determined by Equations 8–10. Eq. 10 comes from Eq. 9.

$$\begin{cases} C_1 = \dfrac{\sqrt{R'(R_0 - R')}}{\omega R' R_0} > 0 & (8) \\[2ex] C_2 = \dfrac{1}{\omega\left\{(\omega L + X') - \sqrt{R'(R_0 - R')}\right\}} > 0 & (9) \\[2ex] L > \dfrac{1}{\omega}\left\{\sqrt{R'(R_0 - R')} - X'\right\} & (10) \end{cases}$$

We provide its practice to students. At first, we give each of their teams a target frequency for impedance matching of the circuit in Fig. 7. They start to measure impedance of the given speaker $Z' = R' + j\left(\omega L' - \frac{1}{\omega C'}\right)$. Then, they make a suitable coil by rotating a supporting tool like pedaling a bicycle, as shown in Figure 8.

Figure 8. A photograph of making a handmade coil.

When the coil fabrication finished, they measure its impedance $Z_\mathrm{L} = R_\mathrm{L} + j\left(\omega L - \frac{1}{\omega C_\mathrm{L}}\right)$, where R_L and C_L are parasitic resistance and capacitance, respectively. They must add these parasitic values to $Z'$and then create a new speaker impedance $Z'' = (R' + R_L) + j\left(\omega L' - \frac{1}{\omega C'} - \frac{1}{\omega C_L}\right)$. The R' and X' in Eqs. 8–10 are changed to $R' + R_L$ and $\omega L' - \frac{1}{\omega C'} - \frac{1}{\omega C_L}$, respectively. According to Eq. 10, the minimum value of L, L_min, can be calculated as $L_\mathrm{min} = \frac{1}{\omega}\left\{\sqrt{R''(R_0 - R'')} - X''\right\}$. If $L > L_\mathrm{min}$, the handmade coil is proven to be suitable for this purpose. After selecting appropriate C_1 and C_2 according to Eqs. 8 and 9, they finally check the combined impedance of the M/B and speaker, Z, to be $50 + j0$ [Ω].

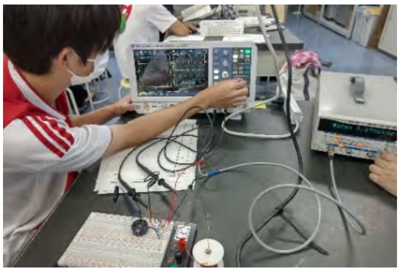

Figure 9. A photograph of impedance matching practice with an audio circuit.

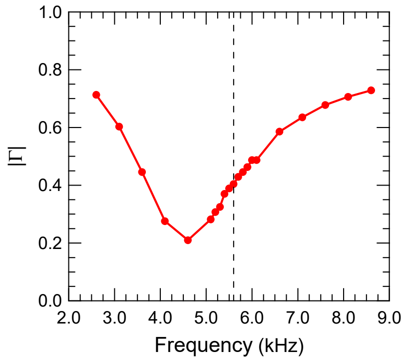

Figure 10. |Γ| value as a function of frequency. The target frequency is 5.6 kHz.

Students measure some parameters for impedance matching, as shown in Figure 9. A student team measured the absolute value of the voltage reflection coefficient, |Γ|, as a function of frequency (refer to Eq. 5), as shown in Figure 10. The target frequency was 5.6 kHz. The minimum value is obtained near the target frequency. The difference between the target and observed frequencies may be due to some line impedance.

The phase variation can be obtained by the Lissajous figures, as shown in Figure 11. Students measure the maximum height of the figure a and the difference between two points crossing the y-axis b. They finally obtain the phase angle θ by Equation 11. Note that this equation depends on inclination of the figure.

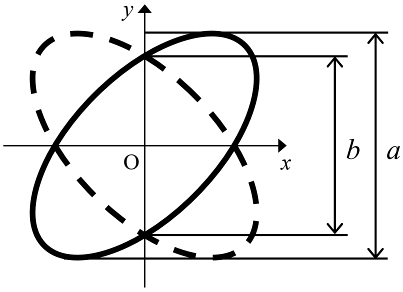

Figure 11. Lissajous figures.

$$\theta = \begin{cases} \sin^{-1}\dfrac{b}{a} & \text{(diagonal right, bold line),} \\ \pi - \left|\sin^{-1}\dfrac{b}{a}\right| & \text{(diagonal left, broken line).} \end{cases} \tag{11}$$

The team also measured θ as a function of frequency, as shown in Figure 12. The |Γ| presented in Fig. 10 is also shown as reference. The frequency where the minimum θ is obtained is the same value of the minimum |Γ|, demonstrating that $Z' = \overline{Z_0}$, as discussed before.

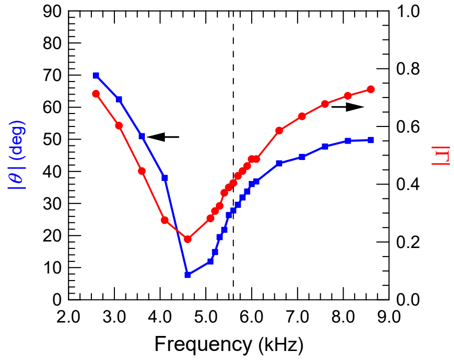

Figure 12. (left) θ and (right) |Γ| values as a function of frequency.

Practice 3: Impedance Matching in MHz Region with VNA

In a quarter of the sixth grade (first grade of the advanced course), students learn impedance matching in the MHz region. The two-port network model is used to analyze arbitrary electrical circuits. The Z- (impedance-) and Y- (admittance-) parameter analyses, as shown in Figure 13, are typical methods. The voltage and current input into a device under test (DUT) from the left side are V_1 and I_1, respectively. Those ones from the right side are V_2 and I_2, respectively. The relationship among these variables is expressed by Equations 12 and 13.

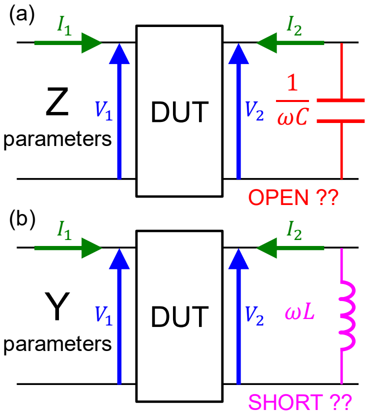

Figure 13. (a) Z- and (b) Y-parameter analyses.

$$\begin{cases} \text{Z: } \begin{bmatrix}V_1\\V_2\end{bmatrix} = \begin{bmatrix}Z_{11} & Z_{12}\\Z_{21} & Z_{22}\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}, & (12) \\ \\ \text{Y: } \begin{bmatrix}I_1\\I_2\end{bmatrix} = \begin{bmatrix}Y_{11} & Y_{12}\\Y_{21} & Y_{22}\end{bmatrix}\begin{bmatrix}V_1\\V_2\end{bmatrix}. & (13) \end{cases}$$

To obtain each Z-parameter from Eq. 12, the left or right hand current, I_1 or I_2, should be zero. In other words, an open condition must be established. However, at a radio frequency, because the capacitive reactance $X_C = {}^{1}/_{\omega C}$ goes to zero, the open condition becomes impossible. Similarly, to obtain each Y-parameter from Eq. 13, V_1 or V_2 should be zero. A short condition must be established. Any conductive lines accompany with inductance. Because the inductive reactance $X_L = \omega L$ goes to infinity at a radio frequency, the short condition becomes also impossible. After all, voltage and current cannot be measured independently at a radio frequency.

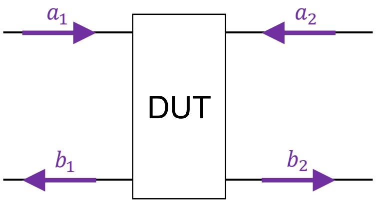

Figure 14. S-parameter analysis.

Instead of the Z- and Y-parameters, we must use S-parameters at a radio frequency. The input and output variables are the square roots of power a_n and b_n, respectively, as shown in Figure 14. The relationship is expressed by Equation 14,

$$\text{S:} \quad \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}. \qquad (14)$$

We obtain $\Gamma = S_{11}$. In the S-parameter analysis, the Smith chart, as shown in Figure 15, is convenient to understand the change of equivalent passive elements. From Eq. 5, we obtain Equation 15 that explains the Smith chart circle,

$$\left(u - \frac{R}{R+1}\right)^2 + v^2 = \left(\frac{1}{R+1}\right)^2, \qquad (15)$$

where $Z \equiv {}^{Z_\ell}/_{Z_0} = R + jX$ and $\Gamma = u + jv$. On the Smith chart, resistance R increases from left to right (0 to ∞). Similarly, inductive reactance $+X$ increases clockwise, and capacitive reactance $-X$ increases anticlockwise. The $|\Gamma|$ equals to the line length (radius) between the measured point A and origin O, and the angle made by the line and positive x-axis indicates its phase angle θ. Impedance matching is accomplished at O, where $(R, X) = (1,0)$ and $(u, v) = (0,0)$. Using the Smith chart, we can know these values visibly without complicated calculation.

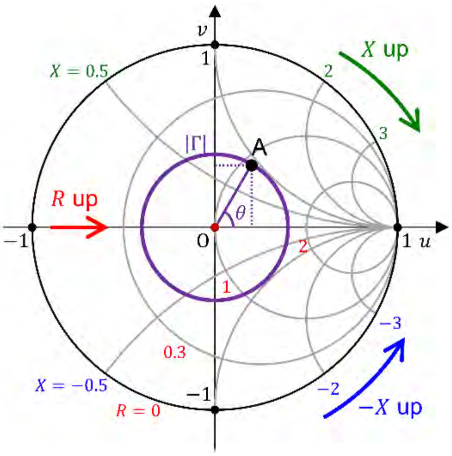

Figure 15. Smith chart.

We made a M/B used in the MHz region by using commercial elements: two trimmer capacitors and an inductor. The load is a simple LCR series. Figure 16 shows these ones.

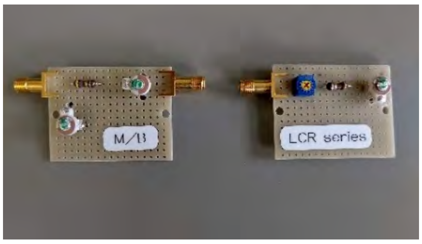

Figure 16. (left) M/B and (right) load for impedance matching in the MHz region.

The S-parameter analysis is performed with a vector network analyzer (VNA). The VNA is one of the most expensive apparatuses in electrical engineering. However, presently we can use a low-cost but high-performance VNA, NanoVNA. A NanoVNA is a palm-size apparatus. It can work either solely or with a control PC. Students set their LCR loads arbitrarily each other, and then they compete for the impedance matching. Figure 17 shows the practice.

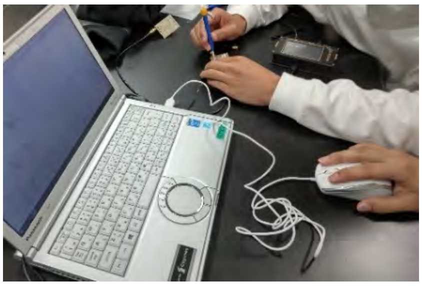

Figure 17. A photograph of impedance matching practice in the MHz region using a palm-size NanoVNA (top) with its control PC (left).

Practice 4: Impedance Matching of Waveguide in GHz Region with VNA

In the following quarter, students learn impedance matching in the GHz region, as a compilation of this education program. When the target frequency reaches GHz, the skin effect in electromagnetism becomes critical. The skin effect demonstrates that the current flows only at the surface of a conductor. The depth where the current can flow is estimated by the skin depth. The depth in copper at 2.45 GHz is approximately 1 μm. Thus, it is difficult to flow large current on a general circuit at such a frequency because the actual line resistance is so high.

To overcome this problem, the electrical power or signal should be flown as an electromagnetic wave in the space that is regulated by a waveguide. Impedance matching in a waveguide is basically to generate a standing wave inside the waveguide so that the short condition is accomplished at the walls. Figure 18 shows a waveguide system. The system is composed of a waveguide-to-coaxial adapter, a straight waveguide, and a dummy load having a sliding short bar to move the end wall. The latter two components are handmade.

The electromagnetic wave in a waveguide takes some propagation modes. The most basic one is the TE_{10} mode, as shown in Figure 19. The TE_{10} electromagnetic wave propagates along the wavenumber vector $\boldsymbol{k}$ by repeating reflections at the wall diagonally. The electric field vector $\boldsymbol{E}$ is along the y-axis, and the magnetic field vector $\boldsymbol{B}$ is on the xz-plane.

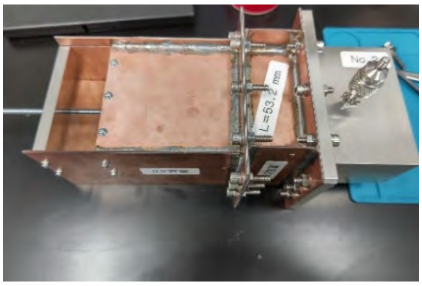

Figure 18. A waveguide system. The system is composed of (right) a waveguide-to-coaxial adapter, (center) a straight waveguide, and (left) a dummy load having a sliding short bar.

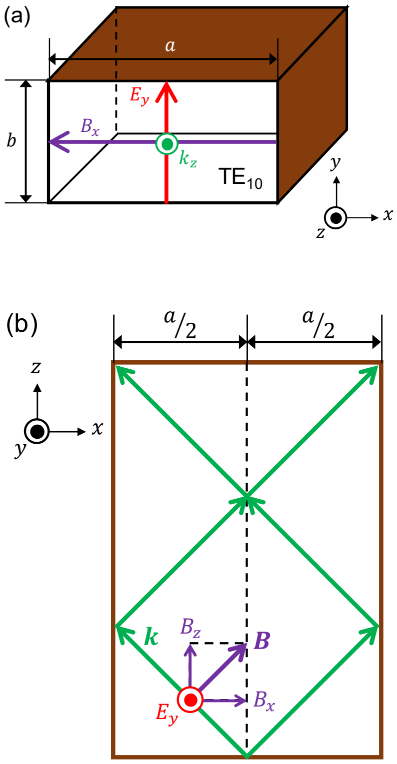

Figure 19. (a) Cross section and (b) top view of a TE_{10}-mode waveguide.

Students measure the S-parameters of a waveguide system using a NanoVNA, as shown in Figure 20. They learn variation of the characteristics by changing straight waveguide (from short one to the long) and moving the sliding short bar of the dummy load.

A student team measured $|\Gamma| = |S_{11}|$ as a function of frequency, as shown in Figure 21. The team obtained the minimum $|\Gamma|$ at 2.66 GHz in a waveguide of which the length is 246.4 mm. Like this, at present we have fortune that we can experience the VNA measurement easily with NanoVNAs.

Figure 20. A photograph of impedance matching practice of a waveguide (bottom) in the GHz region using a NanoVNA (right) and its control PC.

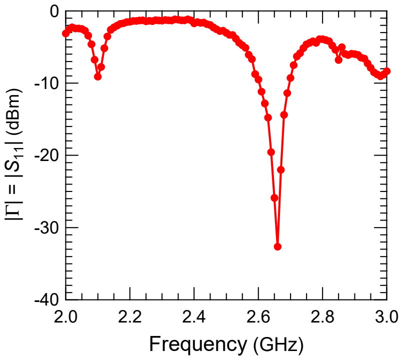

Figure 21. $|\Gamma| = |S_{11}|$ as a function of frequency (the LogMag characteristics in dBm).

Conclusions

A step-by-step education program of impedance matching in Ariake Kosen was explained. The education program comprises four practices. This education starts in a half of the fourth grade from electromagnetism theory with Maxwell's equations including the skin effect and electromagnetic wave (Practice 1). Actual impedance matching of an audio circuit in the KHz region is performed in a quarter of the next fifth grade (Practice 2). Finally, in the sixth grade (first grade of the advanced course), impedance matching of the circuit in the MHz region (Practice 3, a quarter) and that of a waveguide in the GHz region (Practice 4, another quarter) are experienced with the S-parameter analysis using a NanoVNA. Through this program, Kosen students will be expected as radio-frequency electrical engineers.

Acknowledgements

The author (S. T.) acknowledges Mr. K. Ooi, formerly of ADTEC Plasma Technology Co., Ltd. for advising fabrication of waveguides and the NanoVNA-analysis.

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NanoVNA V2 Official Site. https://nanorfe.com/nanovna-v2.html.

Effective use of wearable physical monitors and activity trackers for safe stand-up paddle (SUP) instruction

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Abstract

Stand-up paddle (SUP) is becoming increasingly popular as a water sport requiring balance, strength, and endurance. However, SUP-related accidents and incidents (including fatalities) are on the rise, and the use of wearable body monitors and activity trackers has been proposed to enhance SUP safety. These devices provide real-time feedback on posture, balance, and body movements, allowing instructors to identify potential risks and adjust instruction accordingly. Activity trackers also help people monitor their progress and set realistic goals, contributing to a more effective and enjoyable learning experience. This paper introduces the usefulness of the use of wearable technology in SUP, including fatigue assessment and a system that alerts humans to hazards in the natural environment such as wind and current, and suggests ways in which the device can be used by SUP instructors. In developing this system, we have built a program that can determine the limits of such manoeuvres by acquiring data from actual offshore locations and using statistical methods to analyse the effects of drifting and wind. Based on the results of machine learning, we conducted interviews with experts and people with SUP experience to clarify the usefulness of the program in subsequent risk assessment. The results revealed that manoeuvring limits due to drifting and wind are related to heart rate and SUP behaviour. The findings also revealed the importance of organizing information on various situations, gender, physical fitness, etc. by their profiles to improve accuracy, which will be implemented in the future. In addition, personality and other factors are intervening in the behavioural awareness of participants who receive SUP instruction, and these factors will be examined in the future.

Keywords: maritime, wearable device, human errors

Introduction

SUP (Stand-up Paddle Board Fig. 1) is a water sport where the rider stands on a board and paddles forward and is enjoyed in a variety of directions including racing, surfing, yoga, fishing, river, exercise and foiling. Surfers started it and there are many theories. Initially they were simple, larger versions of surfboards, but more recently they have become more specialised, with improved speed, manoeuvrability, endurance and strength to suit their intended use. They are becoming more popular every year as no special licence is required.

Fig. 1 stand-up paddle (SUP)

On 5 September 2021, one of six people on a SUP led by an instructor was killed in a collision with a fishing boat in Wakasa Bay, about 250 m off Takahama, Fukui Prefecture. The captain of the fishing boat and the instructor were referred to prosecution on suspicion of manslaughter. The sea was calm, and visibility was good on the day of the accident and the instructor was taking photos of the other six people in a row when the accident occurred. Fishing boats are relatively slow and there is little deviation from the course even when the hands are off the boat. Therefore, the accident could have been caused by inattention ahead due to falling asleep or tending to tools. Another possible cause of the accident is that the instructor neglected his duty of care, as the sea was calm and clear at the time of the accident, and he was able to notice surrounding dangers at an early stage.

On 10 August 2021, a man was missing while SUP on Koishigahama Beach, Lake Inawashiro, Aizuwakamatsu City, Fukushima Prefecture. The man had come with five others to teach SUP when he was swept away and went missing and was found dead nine days later. He was not wearing a lifejacket when he was found because of strong winds at the time.

On 9 October 2021, five SUP yoga practitioners were swept away off Chigasaki Fishing Port, Chigasaki City, Kanagawa Prefecture, and were unable to return home.

one of the five was an instructor but had lost contact with the operator. The five were towed away by a passing canoe and were unhurt.

The number of SUP fatalities and injuries has increased in recent years as marine sports have become more popular. (Fig. 2)

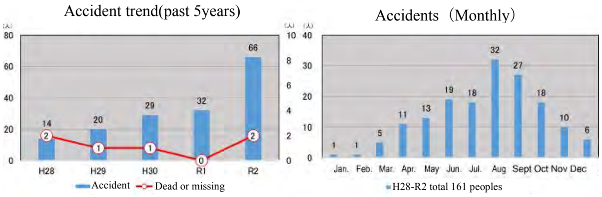

Fig. 2 The number of SUP fatalities and injuries (JCG)

The number of SUP accidents has gradually increased from 14 in 2008 to 66 in 2020. Most of the accidents were non-returnable and were caused by inattention to weather and sea conditions and lack of knowledge and skills. (Fig. 3 and 4)

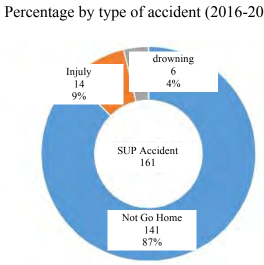

Fig. 3 The number of SUP accidents (JCG)

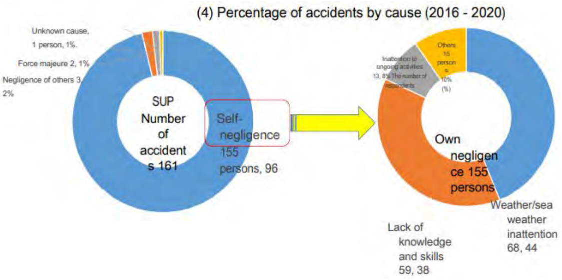

Fig. 4 The number of SUP accidents (JCG)

More than half of the crew had less than one year's experience, and inexperience can be considered a factor in these accidents. (Fig. 5)

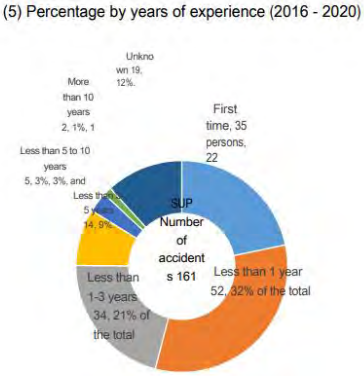

Fig. 5 The number of SUP accidents (JCG)

It can also be seen that SUPs are susceptible to external forces such as weather and sea conditions, as the number of accidents occurring at high wind speeds and high wave heights is high. (Fig. 6).

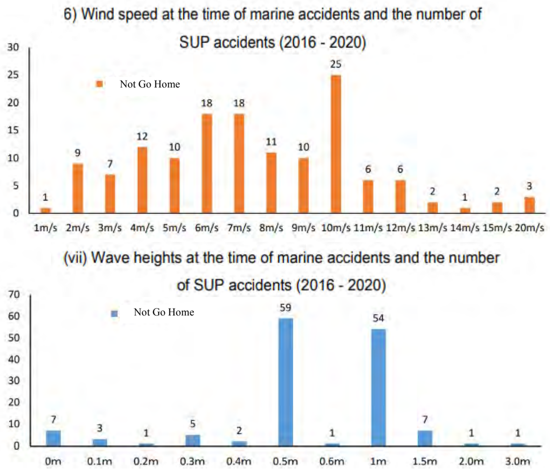

Fig. 6 The number of SUP accidents (JCG)

Although anyone can casually enjoy SUP, it is no exaggeration to say that ocean recreation is a life-threatening activity, as accidents have occurred. Therefore, to protect your life, you must acquire the knowledge to enjoy SUP safely. Knowledge of how to enjoy SUP safely is not difficult to acquire, and includes such things as wearing life-saving equipment such as a lifejacket, learning how to paddle from books and videos before actually doing so, making the decision to stop when the weather is bad, and not overdoing things even if you improve, and only doing what you can do with the skills you have. It is not difficult to enjoy the sport. Other things you need to know include knowledge of weather and sea conditions, board manoeuvrability, and how to take off and land on the shore. After acquiring this knowledge, it is necessary to be able to judge the relationship with other vessels, local rules, and information on the location of the SUP at the time of the SUP.

Materials and Methods or pedagogy

To get an idea of the features of SUP, SUP was carried out in the sea area shown in Fig. 7 using a wearable device.

Fig. 7 Experimental area

To find out the features, a pattern of two days with different tidal conditions and long and short passages was carried out. To perform this pattern, SUP was experienced by six men who were able to paddle the SUP without problems in low wave conditions. They were always fitted with a wearable device. The 'Fitbit sense2' was used as the wearable device. The board used for SUP was a soft board or inflatable board with three fins on the rear part. This has an easy-to-stabilise structure and a straight line for beginners.

Experiments were carried out on 9 and 16 May 2023. The weather was sunny, and the wind speed was rather strong at about 2 m/sec. The tidal currents were opposite on 9 and 16 May but were from offshore towards the harbour (the flow was towards the upper left and lower right according to the graph of results described below).

The validation of the wearable terminals was carried out on land and at sea, in position and speed.

Results and Discussion

In presenting the results, time series data on the wake and speed of each voyage are shown. Each result will also include information on the Dead Reckoning (guess navigation), together with the actual data, to further clarify the forces, including the drifting forces due to currents and the characteristic propulsive forces of the paddles. The calculation method of the Dead Reckoning is based on the mid-latitude navigation calculation method, and the calculated values are the estimated values moving from the trend of 10 seconds ago. The deviation at this time is considered to include the drift force due to the current and the characteristic propulsive force of the paddle, as described earlier.

The long-distance data from 9 May are shown in Experiencer A (Fig. 8,9) and Experiencer B (Fig. 10,11), while the short-distance data are shown in Experiencer C (Fig. 12,13) and Experiencer D (Fig. 14,15). Furthermore, data for the long distance on 16 May are shown for experiencer E (Fig. 16, Fig. 17) and experiencer F (Fig. 18, Fig. 19). Figs. 8, 10, 12, 14, 16 and 18 show the trajectories and Dead Reckoning trajectories. Figs. 9, 11, 13, 15, 17 and 19 show the actual speed and moving average of Velocity (N=10).

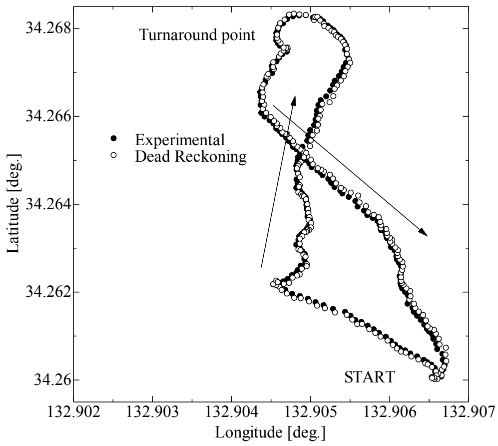

Fig. 8 Trajectory of Experiencer A

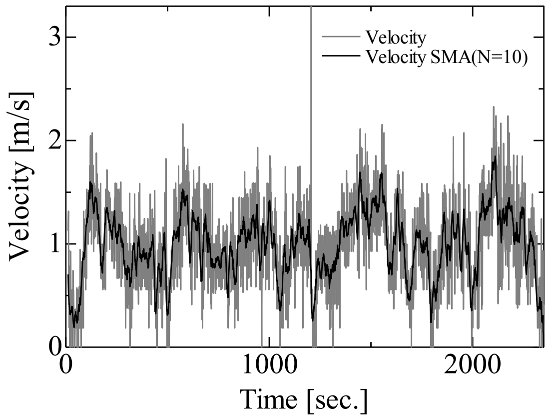

Fig. 9 Time series of velocity of Experiencer A

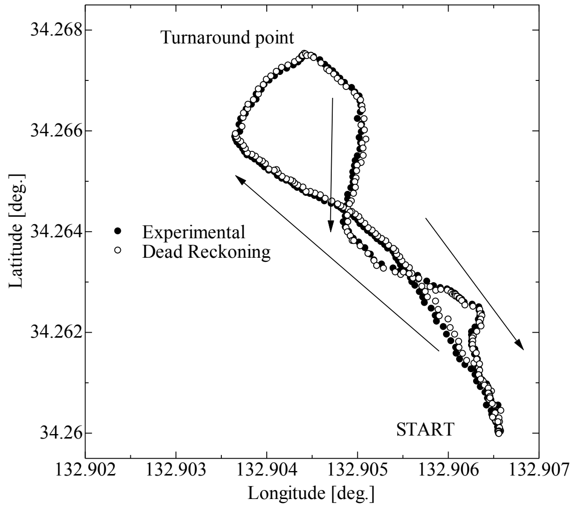

Fig. 10 Trajectory of Experiencer B

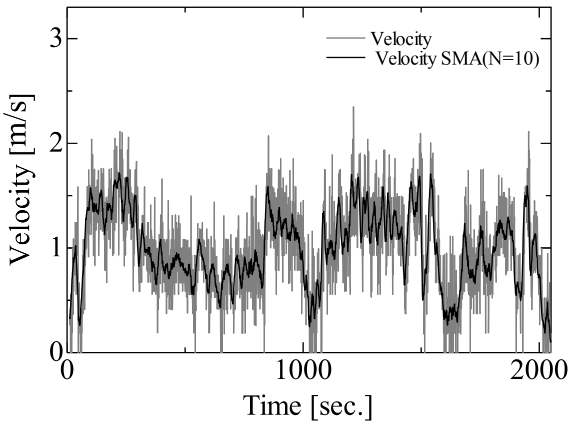

Fig. 11 Time series of velocity of Experiencer B

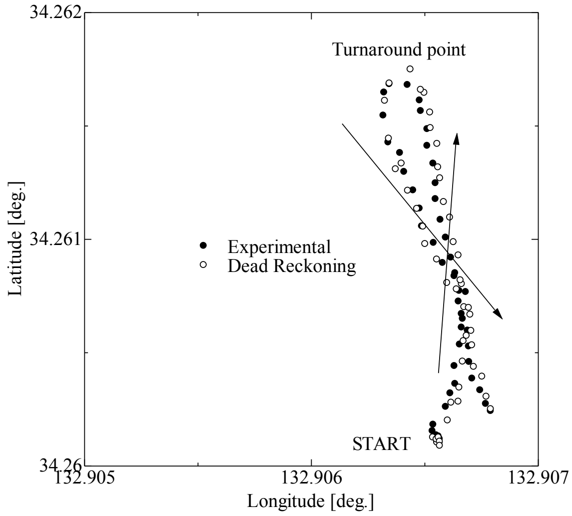

Fig. 12 Trajectory of Experiencer C

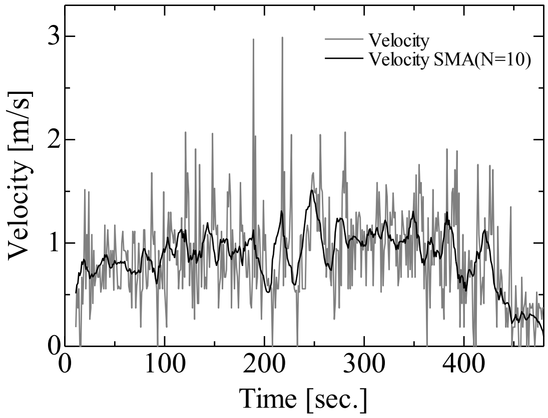

Fig. 13 Time series of velocity of Experiencer C

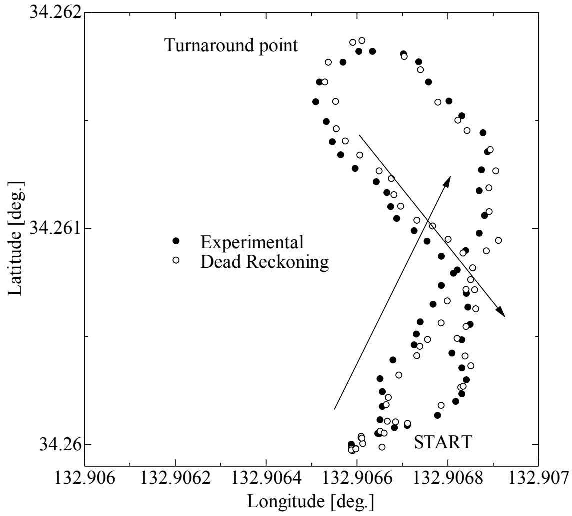

Fig. 14 Trajectory of Experiencer D

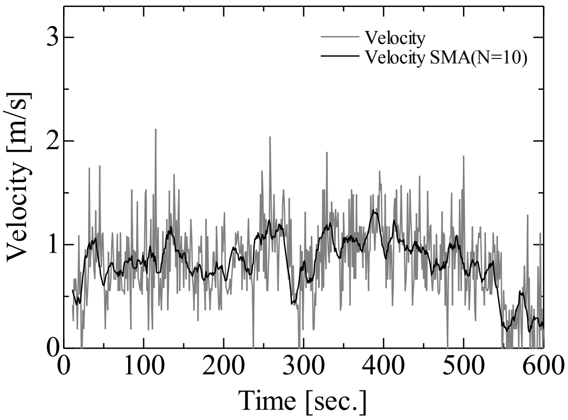

Fig. 15 Time series of velocity of Experiencer D

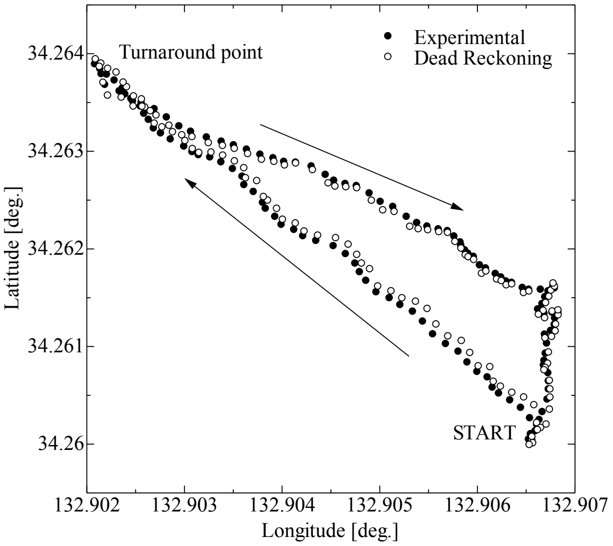

Fig. 16 Trajectory of Experiencer E

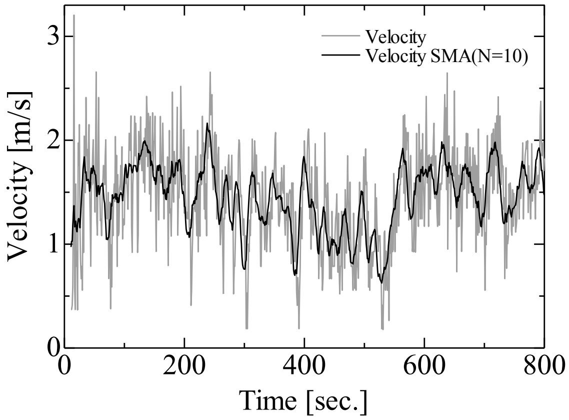

Fig. 17 Time series of velocity of Experiencer E

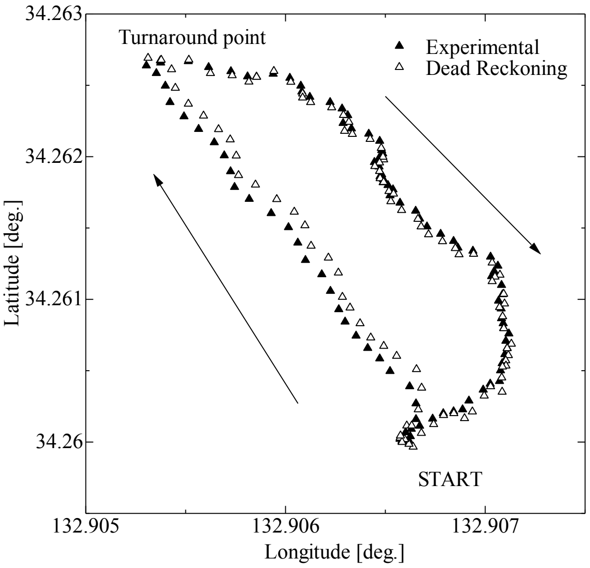

Fig. 18 Trajectory of Experiencer F

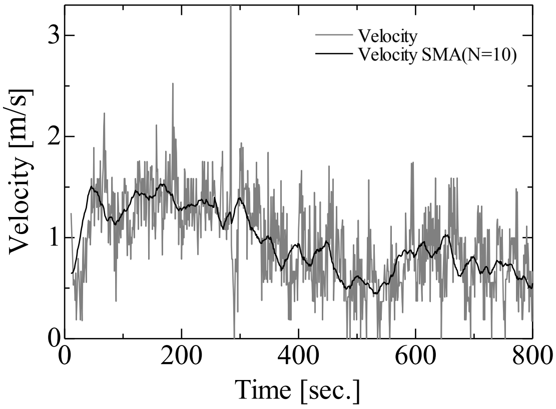

Fig. 19 Time series of velocity of Experiencer F

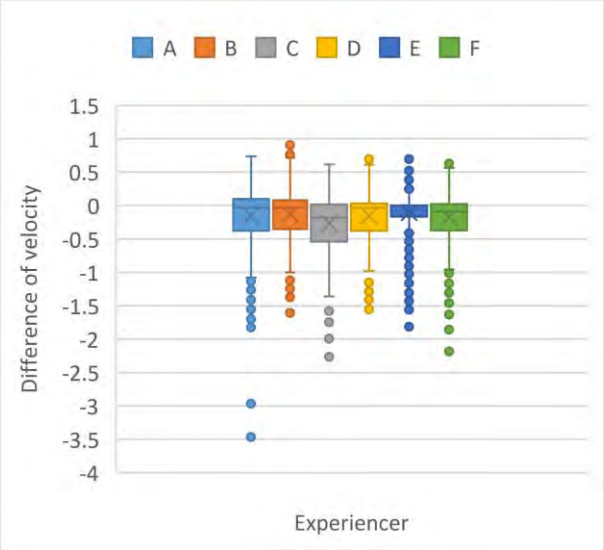

Fig. 20 Box plot of difference of velocity (exp. – D.R.)

The differences between drift and pedal propulsion can be seen in all graphs. This can be further understood broadly as a trend in speed in each experiment. For example, if the board is facing the same direction as the current, the speed increases and thereby the dead reckoning values move away. This may be because the boat may be drifting, which has a significant effect on the current field. In this case, the rowing force is a less relevant situation. Conversely, when the boat is in the opposite direction to the current, the estimated sailing values do not show much difference, and it is considered that the human rowing against it, coupled with the thrust, makes the difference smaller.

Fig. 20 shows a distribution showing the difference between the speeds obtained at the measured and estimated positions of the five individuals. The results show the relationship between drifting and SUP-specific propulsive forces, with zero indicating that these are not acting or are counteracting. The results indicate that when the measured value is higher than the estimated value, the person is more likely to drift, and when the estimated value is smaller than the measured value, the person may be rowing quite hard but not moving forward, and if this situation persists, it is very physically demanding.

Furthermore, the graph shows that the boat is travelling in a zig-zag course, which is not seen in power vessels or canoes. This type of movement is a trajectory unique to SUPs. Such zig-zag trajectories of SUPs are thought to misjudge the apparent relationship from a distant vessel and may lead to collisions.

Conclusions

This study has enabled the use of a wearable device and knowledge of the features of SUPs. In particular, it was considered possible to grasp the characteristics of navigating in a zigzag manner and the fact that drifting and SUP's characteristic paddling propulsion are linked to the trend of the current. Furthermore, it is thought that these monitoring data can be formulated, and that further analysis of heart rate and other data can be carried out using a wearable terminal, making it possible to prevent accidents such as those caused by drifting currents, etc., which make it difficult to return home because of the inability to keep up with one's physical fitness, and thus get lost. This is thought to be possible through the use of wearable terminals.

In the future, it is necessary to further examine whether the combined forces of drifting and SUP's characteristic rowing propulsion are affected by other factors, and to further investigate whether this mechanism is affected by the way of rowing and the centre of gravity.

Reference

Japan Coast Guard (2021), *Incidents of accidents in SUPs*, https://www6.kaiho.mlit.go.jp/watersafety/sup/pdf/01_supaccident.pdf.

FUNDAMENTAL STUDY ON VR SYSTEM FOR SECURING AND DEVELOPING SUCCESSORS IN MOUNTAIN TUNNEL CONSTRUCTION

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Abstract

In recent years, the aging of workers and the decrease in young human resources have progressed in the Japanese construction industry. Therefore, the lack of future successors has become a serious problem. In particular, it is difficult to secure successors in the Japanese tunnel industry due to the low recognition among young human resources and civil engineering students. Under the circumstances, it is necessary to have young people and civil engineering students recognize and understand about the tunnel industry in order to properly construct and maintain tunnels and hand down the technology to the next generation. And, it is essential to develop tools that support the early success of young successors and promote their retention in the tunnel industry. In order to solve such problems, simulated experience tools that utilize Cross Reality (XR) technology have been widely used in the construction industry. For example, in the Japan's tunnel industry as well, several VR tools have been developed for the purpose of safety education and saving labor during tunnel construction. However, the tools have not been sufficiently developed for the purpose of securing successors in the tunnel industry and supporting their early success. Therefore, in this study, a basic Virtual Reality (VR) system that can simulate the situation (Especially, during tunnel face observation) during mountain tunnel construction was developed by using three dimensional (3D) model created based on photogrammetry and the Unity of game engine. And, in order to confirm usefulness of the developed VR system, a total of 18 male and female students (14 civil engineering students and 4 non-civil engineering students) from National Institute of Technology, Matsue College experienced this VR system and conducted questionnaire surveys. As a result, it was clear that it was useful for enhancing recognition of the tunnel industry and initial education for young human resources by utilizing this VR system.

Keywords: *mountain tunnel construction, education, VR, unity, questionnaire survey*

Introduction

In recent years, the aging of workers and the decrease in young human resources have progressed in the Japanese construction industry. Therefore, the lack of future successors has become a serious problem. In particular, it is difficult to secure successors in the Japanese tunnel industry due to the low recognition among young human resources and civil engineering students. Under the circumstances, it is necessary to have young people and civil engineering students recognize and understand about the tunnel industry in order to properly construct and maintain tunnels and hand down the technology to the next generation. And, it is essential to develop tools that support the early success of young successors and promote their retention in the tunnel industry.

Simulated experience tools that utilize the Cross Reality (XR) technology is one of the tools that can solve these problems. In recent years, this technology has been widely used in the construction industry. For example, the tools for architecture visualization and design education and for construction safety education have been developed by utilizing the virtual reality (VR) technology (Wang et al., 2018). In Japan, several VR tools have been suggested for the purpose of education and labor saving of bridge inspection (e.g., Baba et al., 2019; Saito et al., 2021). In the Japan's tunnel industry as well, although several VR tools have been developed for the purpose of safety education and saving labor during tunnel construction, the tools have not been sufficiently developed for the purpose of securing successors and supporting their early success.

Therefore, in this study, a basic Virtual Reality (VR) system that can simulate the situation (Especially, during tunnel face observation) during mountain tunnel construction was developed by using three dimensional (3D) model created based on photogrammetry and the Unity of game engine. And, questionnaire surveys targeting students was conducted in order to confirm the usefulness of this VR system.

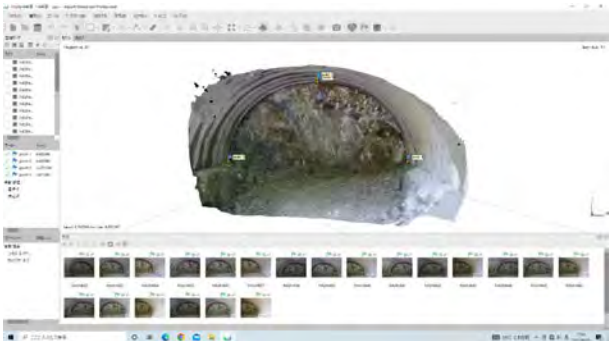


Photo 1 The 3D model around the tunnel face generated by Agisoft Metashape.

Photo 2 The 3D model around the tunnel face imported into the VR space of Unity.

Building Methods and Contents of VR System

VR system of this study was built by focusing on the tunnel face during mountain tunnel construction. The tunnel face is the tip part of tunnel excavation that requires regular observation for safe construction of mountain tunnels. Non construction workers can seldom experience its observation. The building procedure of VR system is as follows.

First, a 3D model (OBJ format) around the tunnel face was generated using Agisoft Metashape for photographic images of the tunnel face in mountain tunnel (see Photo 1). Agisoft Metashape is software that can generate various 3D models after automatically combining the photographic images by distinguishing the color tone and gradation of each pixel of them.

Then, the generated 3D model was imported into a VR space created by the game engine Unity from Unity Technologies (see Photo 2). Finally, various functions such as the teleport function were implemented in the VR space. Thus, visualization of the built VR system was performed by HTC Vive Cosmos Elite, which is VR-HMD (Head Mounted Display) from HTC shown in Photo 3. Table 1 shows the detail of a hardware and names of all software used to perform this VR system.

The detail of implemented functions is as follows. First, the teleport function was implemented so that the user of this VR system could move freely and smoothly in the VR space. And, the pointer function was also implemented so that the user could point out the position of cracks and geological change on the tunnel face in the VR space (see Photo 4). Then, the function that cracks were colored (i.e. the function that the correct/wrong judgment of position of cracks was outputted) was implemented when the user pulled the trigger of controller while pointing the pointer function at the

Photo 3 VR-HMD HTC Vive Cosmos Elite.

Table 1 Hardware and software used in the VR system.

Hardware	OS：Windows 10 Pro CPU：Intel(R) Core(TM) i9-12900KF RAM：128GB Disk space：465GB GPU：NVIDIA GeForce GTX 1650
Software	・Unity ・Microsoft Visual Studio C# ・SteamVR ・SteamVR Plugin ・Agisoft Metashape Professinal

Photo 4 VR system user's viewpoint when using the pointer function.

Photo 5 VR system user's viewpoint after the cracks were colored.

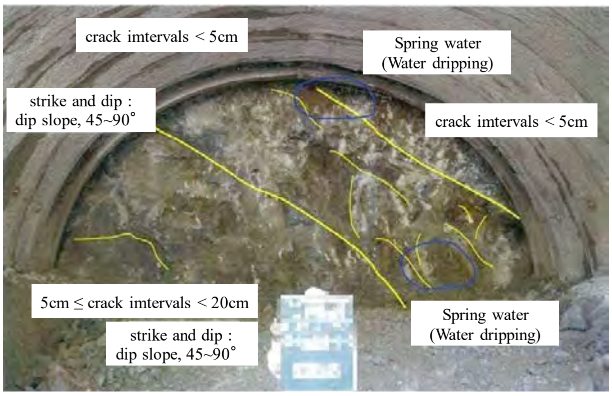


Figure 1 An example of tunnel face sketch in the tunnel face observation data sheet

position of cracks determined by experienced engineers (see Photo 5). In addition, the tunnel face observation data sheet (PNG format) evaluated by experienced engineers was also introduced as a reference for users to observe the tunnel face and evaluate ground conditions in the VR space (see left side of Photo 4). Fig. 1 shows the tunnel face sketch part of the tunnel face observation data sheet in Photo 4.

Results and Discussion of Questionnaire Survey

In order to confirm usefulness of the built VR system, a total of 18 male and female students (14 civil engineering students and 4 non-civil engineering students) from National Institute of Technology, Matsue College experienced the VR system and conducted questionnaire surveys. Photo 6 shows an example of scene experiencing the VR system. Table 1 shows each item and choice of the questionnaire. Each item of the questionnaire was created to confirm the experience in mountain tunnel construction of experienced person of the VR system (item (a)), the visibility of the VR system (item (b)~(d)), and the usefulness for developing young engineers (item (e)). At the end of the questionnaire, other opinions such as impressions and improvements were invited by providing an additional comment column.

Figure 2 shows the results of obtained questionnaire survey. It can be confirmed from Figure 2(a) that most of the students experienced the VR system have never stood in front of a tunnel face without shotcrete. In addition, it is clear from Figure 2(b)(c) that it is possible to moderately visualize cracks and rock types similar to the tunnel face observation data sheet evaluated by experienced engineers in the built VR system. From these results, it seems that even inexperienced persons in mountain tunnel construction can easily simulate the situation during tunnel face observation by utilizing this VR system. Therefore, it is considered that it can contribute to enhancing of recognition about the tunnel industry by having young people and civil engineering students experience this VR system more.

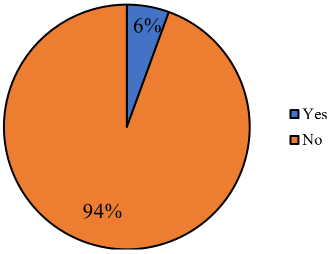
On the other hand, it is obvious from Figure 2(d) that it is difficult to visualize spring water similar to that in the tunnel face observation data sheet in this VR system. This may be improved by raising resolution of the 3D model. However, there is a possibility that it is not

Photo 6 The example of scene experiencing the VR system.

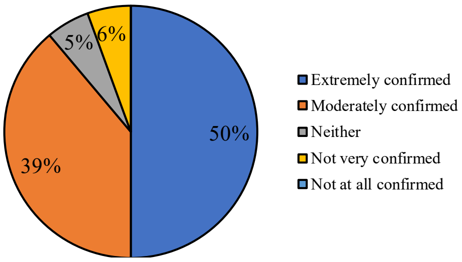
Table 1 Each item and choice of the questionnaire.

(a)	Q : Have you ever stood in front of a tunnel face without shotcrete? A : (1) Yes (2) No
(b)	Q : Was it possible to confirm cracks in the VR space similar to those in the tunnel face observation data sheet evaluated by experienced engineers? A : (1) Extremely confirmed (2) Moderately confirmed (3) Neither (4) Not very confirmed (5) Not at all confirmed
(c)	Q : Was it possible to confirm rock types in the VR space similar to those in the tunnel face observation data sheet evaluated by experienced engineers? A : (1) Extremely confirmed (2) Moderately confirmed (3) Neither (4) Not very confirmed (5) Not at all confirmed
(d)	Q : Was it possible to confirm spring water in the VR space similar to that in the tunnel face observation data sheet evaluated by experienced engineers? A : (1) Extremely confirmed (2) Moderately confirmed (3) Neither (4) Not very confirmed (5) Not at all confirmed
(e)	Q : Did you think that the function that the correct/wrong judgment of position of cracks was outputted was useful for initial education of tunnel face observation? A : (1) Agree (2) Moderately agree (3) Neither (4) Not very agree (5) Disagree

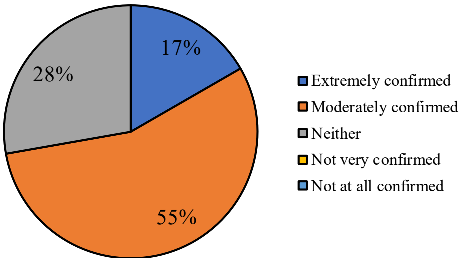
suitable for visualizing by VR because there are cases like seepage in the spring water on the tunnel face. In addition, there were opinions from the additional comment column that it was difficult to see characters on the tunnel face observation data sheet and to understand described section of rock types on it. Although there are some problems as described above, it was clear from Figure 2(e) that the function that the correct/wrong judgment of position of cracks was outputted was useful for initial education of tunnel face observation for young human resources.



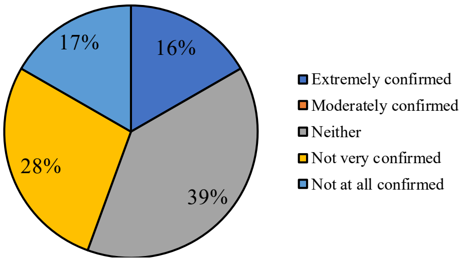
(a) Have you ever stood in front of a tunnel face without shotcrete?



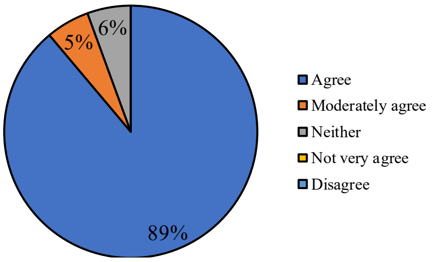
(b) Was it possible to confirm cracks in the VR space similar to those in the tunnel face observation data sheet evaluated by experienced engineers?



(c) Was it possible to confirm rock types in the VR space similar to those in the tunnel face observation data sheet evaluated by experienced engineers?



(d) Was it possible to confirm spring water in the VR space similar to that in the tunnel face observation data sheet evaluated by experienced engineers?



(e) Did you think that the function that the correct/wrong judgment of position of cracks was outputted was useful for initial education of tunnel face observation?

Figure 2 The Results of questionnaire survey (n = 18)

Conclusions

In this study, the basic VR system that can simulate the situation during tunnel face observation in mountain tunnel construction was developed by using 3D model created based on photogrammetry and the Unity of game engine. And, questionnaire surveys targeting students was conducted in order to confirm the usefulness of this VR system. As a result, it was clear that it was useful for enhancing recognition of the tunnel industry and initial education for young human resources by utilizing this VR system.

In future, this VR system will be enhanced by improving the resolution of 3D model and conducting questionnaire surveys for experienced tunnel engineers.

Acknowledgements

I would like to thank Shimane Prefectural Government for providing photographic images of tunnel face.

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USE OF REMOTE ACCESS TECHNOLOGIES FOR CYBERSECURITY EDUCATION IN POST-COVID ERA

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Abstract

After three years of isolation, Hong Kong is entering the post-COVID era. The crisis has exposed a significant challenge in delivering Cybersecurity training and education. There were no face-to-face classes and hands-on labs/practical sections during the last three years. Most of the teaching activities must be delivered with online mode. Students were required to complete the hands-on practical exercises of cybersecurity-related modules at home. With the application of virtualisation technology, most of the students can complete the training exercises at home. However, it was challenging to monitor the progress of students. In case there was any problem encountered by the student. It was almost impossible to troubleshoot in such a remote environment. Due to the limitation of the Wi-Fi/broadband router at home, it was also impossible to pass through the Wi-Fi/broadband router to access the student's home internal network to troubleshoot.

Because of such a challenge, we should apply remote access technology to support and monitor student progress in practical labs, especially for different kinds of server/system administration modules. In cybersecurity, remote access technology for penetration testing can be applied to solve the problem. Open-source penetration testing tools may become a feasible solution for monitoring and supporting tools for practical labs at home. Reverse-shell agency script generation tool can be used to create a system monitoring agency for tracking the activities of students doing their practical labs at home. Also, the command-and-control server (C&C) can be used as the central console. If troubleshooting is required, the lecturer/trainer can perform different operations through the C&C server to the student virtual machine. This model can develop into a full-fledged online training system for delivering cybersecurity practical labs.

Keywords: *Cybersecurity, System Administration, Command and Control Server, C&C, Adversary Tools, Reverse Shell, Shellcode, Red Teaming, Remote Access*

Introduction

COVID-19 has disrupted students' lives in various ways, including the operation of the Vocational and Professional Education and Training (VPET) sector in Hong Kong. Traditionally, each module of an IT-related Higher Diploma programme at the Hong Kong Institute of Vocational Education (HKIVE) comprises lectures and practical labs. However, most campuses have been locked down due to the pandemic, making it impossible to deliver face-to-face lectures and practical labs.

Lectures can be easily changed from face-to-face to online through video conferencing platforms such as Microsoft Teams and Zoom, with slightly less interactive Q&A sessions. An advantage of this approach is that students can revisit lectures to clarify any parts they didn't understand during the e-lecture. However, practical labs pose significant challenges, especially for system and network administration and penetration testing modules. Troubleshooting is complex, and the lecturer can only rely on screen captures provided by students to identify issues, which can be time-consuming and not scalable. If there is more than one student with problems, the lecturer can only help some of them simultaneously.

Additionally, remote access to student virtual machines is not possible due to home network configurations. Therefore, a tailor-made lab monitoring and administration system is needed to support students doing practical labs at home. The system should provide monitoring functions so the lecturer can quickly identify the problem in each virtual machine through the central dashboard or console. However, the development cost for such a tailor-made system is expensive and requires a long time to develop.

As a lecturer teaching Cybersecurity, I find that most penetration testers already use such a platform, and it is open-source and free. This paper demonstrates how to use a communication and control (C&C) server, a penetration testing tool, to effectively and efficiently support students in their Linux server administration labs at home. This platform provides a central dashboard/console for the lecturer to monitor each virtual machine and identify any issues quickly. This open-source solution offers a practical and effective solution for supporting IT practical home labs for VPET institutions facing similar challenges.

Lab Environment at Student Home

Before going into details of our implementation, it is essential to understand the student home lab setup. The diagram below shows the network environment for the student home lab. Students run the VMware workstation on their PC, and all the lab servers run under the VMware workstation virtual environment. The server virtual machines (VMs) are connected to the host PC network through VMware NAT virtual network. The student PC (host of VMware workstation) is connected to the Internet (the Internet Service Provider) through the home wifi/broadband router with NAT. It means the server VMs are running in a private network and cannot be assessed from the Internet.

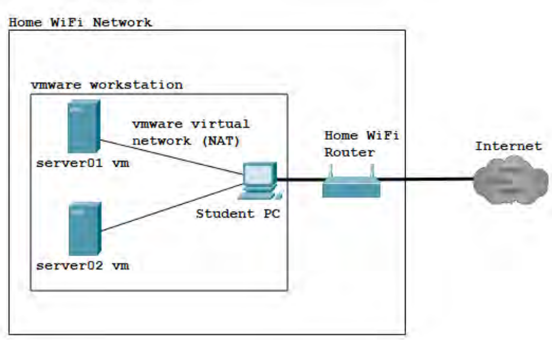


Figure 1 Network environment for student home lab

Terminologies Used in Penetration Testing

To understand the proposed solution to remote lab monitoring, it is crucial to understand the terminologies used in Cybersecurity, especially the terms related to penetration testing.

Command and Control Server (C&C): Command and control are defined as a technique threat actors use to communicate with compromised devices/servers over a network. C&C usually involves one or more covert channels, but specific mechanisms can vary greatly depending on the attack. Attackers use these communication channels to deliver instructions to the compromised devices to download additional malware, create botnets, or exfiltrate data.

A command-and-control server (C&C) is a computer that threat actors use to send instructions to compromised systems. They aim to direct infected devices into performing further malicious activities on the host or network. Many open-source command-and-control servers are available, e.g., Caldera, Silver, and Empire.

Reverse Shell: A reverse shell is a shell session established on a connection initiated from a remote machine, not the attacker's host. Attackers who successfully exploit a remote command execution vulnerability can use a reverse shell to obtain an interactive shell session on the target machine and continue their attack. Reverse shots can also work across a NAT or firewall.

CALDERA Terminologies

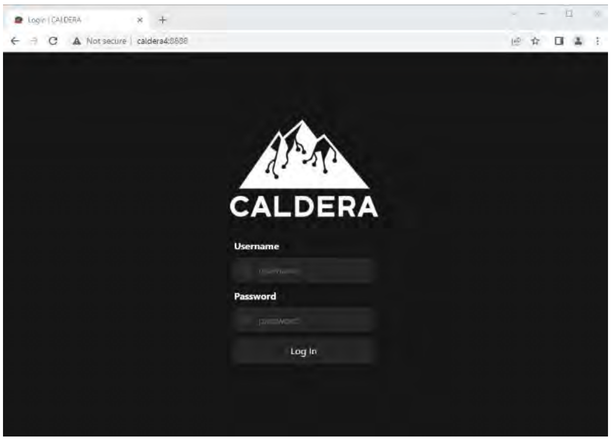


Figure 2 CALDERA Web Console

To fully realise the potential of the C&C framework, CALDERA, you must familiarise yourself with the following terminologies.

CALDERA is a cyber security framework designed to run autonomous breach-and-simulation exercises efficiently. It can also run manual red-team engagements or automated incident responses. CALDERA is built on the MITRE ATT&CK™ framework and is an active research project at MITRE.

Ability: An ability is a specific ATT&CK tactic/technique implementation that can be executed on running agents. Capabilities will include the command(s) to run, the platforms/executors the authorities can run on (ex: Windows / PowerShell), payloads to have, and a reference to a module to parse the output on the CALDERA server.

Adversary: Adversary in cyber security is a term used to describe a malicious actor or group of actors attempting to gain unauthorised access to a computer system or network. Adversaries can range from individual hackers to organised crime syndicates, and they can use various techniques to gain access to a system. In CALDERA, adversary profiles are groups of abilities representing the tactics, techniques, and procedures (TTPs) available to a threat actor. Adversary profiles determine which commands will be executed when running an operation.

Agents are software programs installed on target hosts/clients that connect back to CALDERA at specific intervals to get instructions. Agents communicate with the CALDERA server via a contact method initially defined at agent installation.

Scenario

The following lab scenario is used as a showcase to demonstrate how to apply the remote access technology used by the penetration tester. Five students are required to complete a simple Linux server administration lab exercise. It is to install and set up the Nginx web server in a CentOS 9 Stream server. The CentOS stream server runs under a VMware workstation in the student PC. The tasks for each student include Nginx installation, creating a simple web page, and testing for Nginx server operation. The lecturer must monitor all students' progress and check which task is completed successfully. If there is any problem, the lecturer should troubleshoot within the student's CentOS Stream server VM.

Demonstration/ShowCase

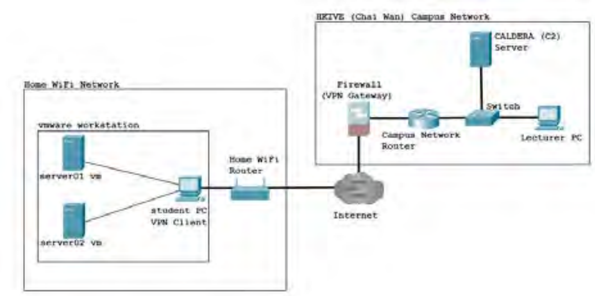
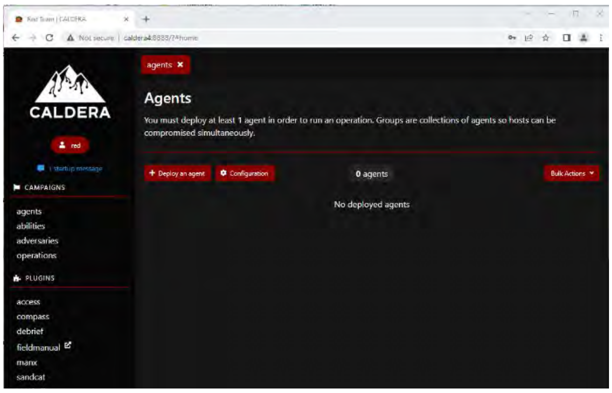


Figure 3 Network setup for home lab monitoring system using CALDERA

The above diagram shows the setup of the proposed solution for remote monitoring of the server administration lab using CALDERA. Using the terminologies of Cybersecurity, the lecturer acts as an adversary in CALDERA; all students act as victims, and the server VMs administered by the students are the victim servers.

The lecturer uses the agent script generation function in CALDERA to generate the reverse shell agent script for the Linux platform, as shown in the diagrams below.

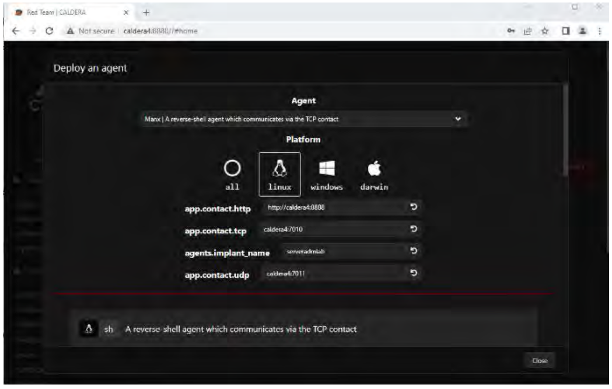


Agents

You must deploy at least 1 agent in order to run an operation. Groups are collections of agents so hosts can be compromised simultaneously.

No deployed agents

Figure 4 CALDERA – agent script generation

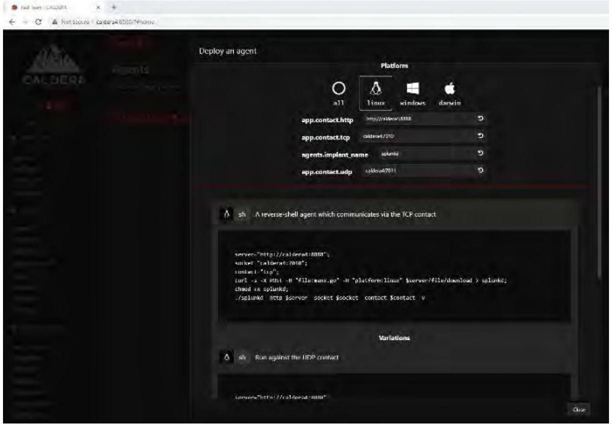


Manx | A reverse-shell agent which communicates via the TCP contact

app.contact.http http://caldera4:8888
app.contact.tcp caldera4:7010
agents.implant_name serveradmlab
app.contact.udp caldera4:7011

A reverse-shell agent which communicates via the TCP contact

Figure 5 CALDERA- platform selection for agent script generation



app.contact.http http://caldera4:8888
app.contact.tcp caldera4:7010
agents.implant_name splunkd
app.contact.udp caldera4:7011

A reverse-shell agent which communicates via the TCP contact

```
server="http://caldera4:8888";
socket="caldera4:7010";
contact="tcp";
curl -s -X POST -H "file:manx.go" -H "platform:linux" $server/file/download > splunkd;
chmod +x splunkd;
./splunkd -http $server -socket $socket -contact $contact -v
```

Run against the UDP contact

```
server="http://caldera4:8888"
```

Figure 6 CALDERA – generated agent script

The agent script can be emailed or posted in Moodle (VTC e-learning platform). Students download and execute the agent script in their server VM. Then, the lecturer can identify each student's virtual machine in the CALDERA Agents console (as shown in Figure 7).

Figure 7 CALDERA Agents Console

To check tasks assigned to students, the lecturer must set up a series of adversary abilities. Each ability corresponds to one or a series of Linux commands for checking whether a task is completed. Then, these abilities are stored under an adversary profile. The diagrams (Figures 8 and 9) below show the abilities created and the corresponding adversary profile in CALDERA.

Figure 8 CALDERA – abilities

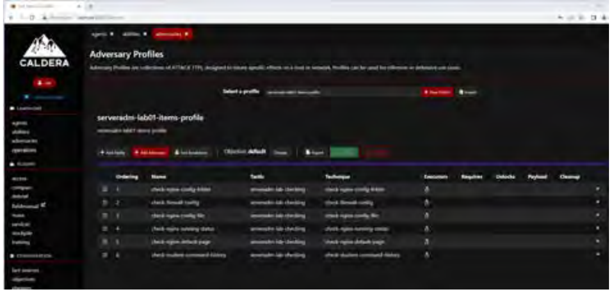


Figure 9 CALDERA – adversary profiles

After the above setup, the lecturer can check each student's progress by creating an operation and executing the adversaries profile created in the previous step. The diagrams (Figures 10 and 11) show the progress of assigned tasks. If it is in green colour, it means the student completed the assigned tasks successfully. The red colour indicates the job is not complete.

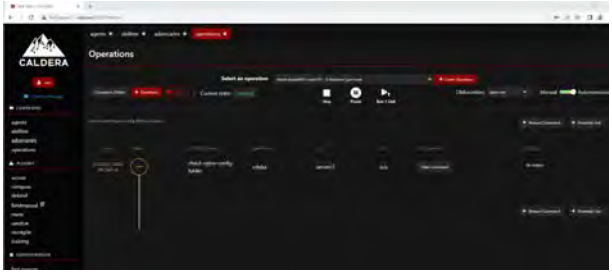


Figure 10 CALDERA console for an operation – checking the progress of a selected student

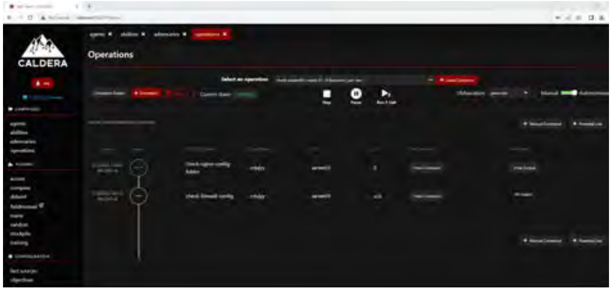


Figure 11 CALDERA console for an operation - check whether a task is completed.

Figure 12 Display output of checking script for a particular task

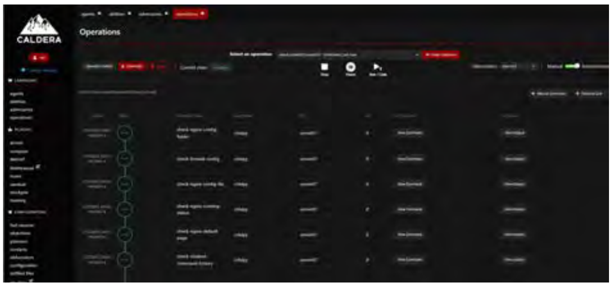


Figure 13 CALDERA console for checking all assigned tasks of a student

The lecturer can also check all the student's progress in an operation. The diagrams (Figures 14 and 15) below show the operation console for checking all students' progress. The result can be output to JSON format for further processing, such as marking and recording each student's performance in this lab.

Figure 14 CALDERA Console for checking the progress of all students

Figure 15 CALDERA Console to view the status of all students

During the lab section, if any student needs troubleshooting, the lecturer can issue Linux commands directly to the student server VM through the operation tab of the CALDERA operation console. The output of the controls can be viewed directly in the console. It can help to identify the problem of the student effectively. The following diagrams (Figures 16 and 17) are an example of the lecturer trying to check the status of SELinux by using the Linux command, quality, and the command output can be viewed from the CALDERA console operation tab.

Figure 16 Execution of troubleshooting commands

```
SELinux status:                 enabled
SELinuxfs mount:                /sys/fs/selinux
SELinux root directory:         /etc/selinux
Loaded policy name:             targeted
Current mode:                   enforcing
Mode from config file:          enforcing
Policy MLS status:              enabled
Policy deny_unknown status:     allowed
Memory protection checking:     actual (secure)
Max kernel policy version:      33
```

Figure 17 Output of the troubleshooting commands

Further Development

CALDERA provides a range of built-in adversary profiles, each with its own abilities corresponding to Mitre Att@ck Tactics, Techniques, and Procedures (TTPs). By making only minor modifications, some of these adversary profiles can be directly applied to labs in different Cybersecurity modules, including Penetration Testing, Windows Administration and Security, and Digital Forensics and Incident Response.

All data collected by CALDERA can be output in various formats, such as JSON, which can be used to generate lab progress reports. Automation scripts can be developed to automatically grade assessments.

CALDERA supports the development of plugins; it is possible to create a highly automated monitoring system that provides interactive support to students performing their labs any time at home. This system can also support or guide students at certain automatic levels, making the learning process more efficient and effective.

Conclusions

Laboratory work or hands-on practical labs are considered at the heart of learning in the discipline of Cybersecurity and can substantially impact students' learning outcomes. Due to the lockdown of COVID-19, it was not possible to have face-to-face classes or on-premises hands-on practical labs for the last three years. Students do their practical lab exercises at home with virtualisation technology. In case there is a problem encountered, the teacher/lecturer is extremely difficult to perform troubleshooting. A cost-effective and scalable remote lab monitoring and supporting system is needed. Open-source Communication and Control server (C&C) perfectly matches the requirement. This paper demonstrates how to apply the remote monitoring technology of Cybersecurity to effectively and efficiently support home labs.

In conclusion, the post-COVID era has brought about unique challenges in delivering cybersecurity education remotely. However, remote access technologies like the open-source communication and control server CALDERA can effectively support and monitor student progress in practical labs. By using this technology, instructors can troubleshoot problems in real-time, track student progress, and apply automatic scripts to assess the lab work performance of the student. This technology could become a full-fledged online training system for delivering cybersecurity practical labs. As such, it represents a valuable tool for cybersecurity education in the post-COVID era and beyond.

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A Development of Hands-on Training Materials
to learn Network Technology in a Police Academy

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Abstract

We present hands-on training materials to learn network technology in a police academy for officers who are not specialized cybercriminal. This material environment contains three virtual machines running Linux in a PC, but it requires the PC to come with 8GB memory and 50 GB space in storage. This is not severe conditions, and they can do this practice with ordinary home PCs. In this material, students could learn data link layer connection between machines, IP address assignment, difference between IP routing, NAT and proxy, and cache and load balancer functionality in reverse proxies in half day class.

Keywords: *non-engineer, network, practice, Linux, Virtual Machines*

1.Introduction

Traditionally, the purpose to learn network technology has been training engineers who can build and operate networks. In recent years, however, students who learn network technology do not always hope to be engineers, because their study purpose is investigating cybercrime or promoting security skill. We categorized them into two groups. The former are the engineer-oriented students, and the latter are the non-oriented group.

Network technology training often comes in classroom lecture and practical training; hands-on. The lectures are for learning the concepts necessary for network technology, and do not differ between engineer-oriented learners and non-engineer-oriented learners. The hands-on are to aim to learn the configuration skills of specific network vendor's equipment. However, device configuration is not a necessary skill for the non-oriented learners. Therefore, this tends to result in classroom-only training that omits hands-on for the for the non-oriented learners. However, since the daily work of non-engineers is not engineering, the lectured knowledge is quickly forgotten. So, hands-on is necessary for them. What kind of environment and content should be used for the hands-on of the non-engineer-oriented learner? This is the subject of this paper.

An example of such a non-oriented learner would be a police officer who does not specialize in cybercrime, but works in the criminal division, non-cyber security or a police department.

As a prerequisite for the development of hands-on materials, organizations of non-engineers do not have a test bed, space or budget to install network equipment, etc. So, we would like to do the hands-on using only PCs. The PCs should not have free access to the Internet for security reasons. The participants are not familiar with advanced command operations, but they hope to be able to use a minimum of commands through the practical training.

We present virtual machine environment working standalone PCs to learn network technologies. This environment contains three virtual machines running Linux, but it requires PC to come with 8GB memory and 50GB space in storage. This is not severe conditions, and they can do this practice with ordinary home PCs. In this material, participants could learn data link layer connection between machines, IP address assignment, difference between IP routing, NAT and proxy, and cache and load balancer functionality in reverse proxies in half day class of a police academy.

In the following, we present some related works and discuss environment of the practice from chapter2 to 4. Chapter 5 presents specific practical nine issues. The items are designed to assume the techniques and skills that police officers will need in their operations.

2.Related Works

There have been several studies [1][2] on teaching engineers in special environments [3] and on teaching non-engineering disciplines to engineers. There is also an initiative called Challenge-Base Learning, which provides hands-on training and deepens knowledge [4]. In this study, we are conducting an educational initiative that includes hands-on training for participants in non-engineering positions. However, we could not find any papers dealing with the education of non-engineering students in engineering. Although this project is unique, it is not a rare case, and it is expected that the need for education like this project will be recognized in the future as network technology becomes more widespread.

3.Background and Goal

The number of crimes that use networks has been increasing in recent years, requiring police officers to be knowledgeable about network technology in police investigations. The author of this paper is a part-time instructor of a police academy and had to plan the objectives and curriculum of the lecture. Based on the intention of police executives, the goal was set not to train a small number of specialists, but to enable more police officers to learn basic networking skills, not only through lectures, but also through practical training. The following sections describes training materials designed to teach the skills necessary for first response to a criminal investigation.

4.Environment and Objectives

In police academies, there are almost no restrictions on computer specifications, and we assume a laptop computer of a class that is generally available on the market.

- ✓ CPU of about IntelCore5i
- ✓ Memory: 8G
- ✓ About 50 GB of free storage space
- ✓ No network equipment other than PCs may be used for training.

Network use is restricted, and it is forbidden to connect from outside to inside, to download files from external servers, or to log in to external servers via ssh or other means.

The goal to be achieved in this environment is to deepen the knowledge of participants who have completed a classroom course on IP networking through hands-on training.

The limitation of using only PCs networking equipment, prohibited connecting routers and other network devices, is due in part to a small budget and inability to purchase networking equipment that is more expensive than PCs, but the goal of the training is not to familiarize the trainees with the use of a particular manufacturer's networking equipment. What is the technology being learned used for? The goal is to understand how these technologies affect police investigations. The trainees are not technicians, and the purpose of the course is not to become network technicians. The course material needs to be designed with this difference in mind.

(Assumed skills of the student)

- ✓ Students do not have the skills to create and modify configuration files using an editor or other tools.
- ✓ They can use basic Linux commands such as file copy command (**cp**) and server start command (**systemctl**).

For these prerequisites, the following materials should be prepared in advance.

- ✓ Linux will be used as the network node.
- ✓ Students will not perform any Linux installation work.
- ✓ Linux distribution will be Linux Mint with low memory usage.
- ✓ Linux will be run on a PC as a Virtual Machine.
- ✓ Application software required for the training should be installed in advance.
- ✓ Application configuration files required for the training will be installed in advance, and students will replace them with cp commands as needed.

Based on these assumptions, instead of using network equipment from a specific network vendor, a hypervisor that can virtually generate multiple network nodes within a single PC was used. We chose VirtualBox [6], which runs on both Windows PCs and MacBooks. In addition, open-source Linux is used as the operating system that runs in the virtual machine generated by the hypervisor. We will use Mint Linux [5], which is lightweight and easy to operate and can run multiple virtual machines on a PC.

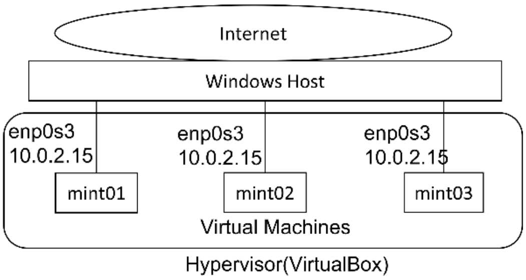


Fig.1 Virtual Machines and Hypervisor used in this hands-on course. Each Machine is installed Linux Mint

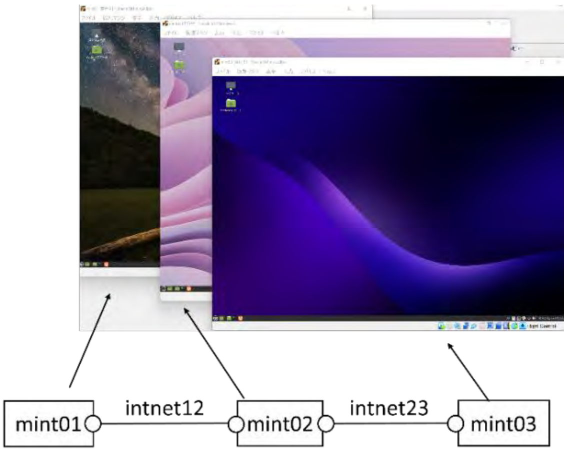


Fig.2 Desktops of Virtual Machines

5.Exercises

To create educational materials for the investigation of server logs, which will enable students to understand basic network technology and its meaning. To this end, the following nine exercises were made to the students.

Ex1) Start and Three Virtual Machines in your PC and Login them.

The virtual machines required for the training are copied to the trainees' PCs in image files and imported into VirtualBox, hypervisor software. It is assumed that the initial network configuration has three separate VMs as shown in Figure 1. Each VM has its own link for Internet access, but there is no inter-VM connection. The trainee powers up the three VMs and logs in. logs in to the VMs.

After logging in, the desktop of each VM appears. The three VMs, each with the hostname mint01/02/03, have different desktop wallpapers pre-set for easy identification shown in Figure2.

Ex2) Install Network Adaptors and Connect them to build a Network of Star Topology.

As shown in Figure3, add the necessary network adapters to the VMs and connect them to the internal network. Internal network, although it is a connection between VMs, corresponds to the process of attaching network adapters and connecting them to each other via Ethernet in actual network equipment. Make them aware that they can work on the physical layer and the data link layer.

The internal network connecting mint01 and 02 is intnet12, and the internal network connecting mint02 and 03 is intnet23.

Ex3) Assign IP address on each interface and Confirm Link connection with the ping command.

Assign IP addresses to the network interfaces added in Ex2: the network address of intnet12 is 192.168.12.0 and the network address of intnet23 is 192.168.23.0 in Figure4. To avoid simply digesting the assignment, as an optional assignment, mint02 is asked to experience that when the network mask is varied, it was possible to connect on 192.168.12.0/24 but not on 192.168.12.0/25, and to consider why this is the case. The host number is assigned a larger value than 128.

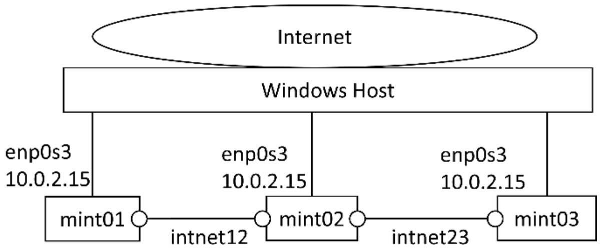


Fig.3 Data Link Interconnections between VMs

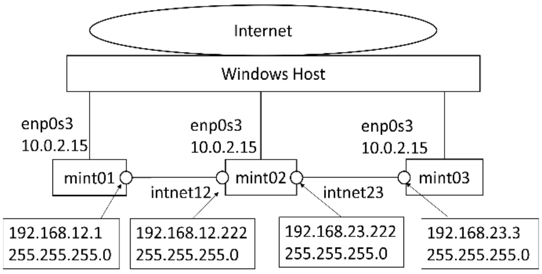


Fig.4 IP Address Assignment on each Interface

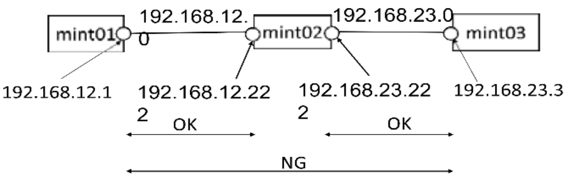


Fig.5 mint02 would not replay any packets before IP forwarding setting.

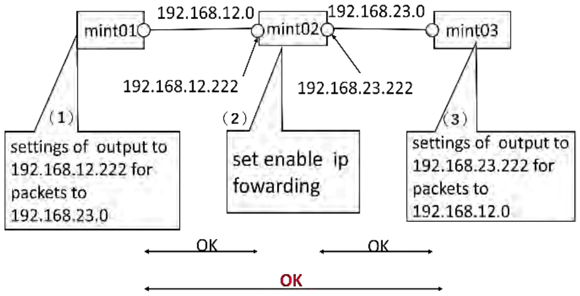


Fig.6 mint01 can reach mint03 after IP forwarding setting on mint02.

Ex4) Set IP forwarding on mint02 and Conform Network Connection between mint01 and mint03.

The ping command confirms that IP reachability between adjacent VMs has been achieved by assigning IP addresses. However, reachability between mint01 and mint03 can not reach each other (Figure 5). This is where the concept of a router must be understood: mint02 must be configured to relay packets not addressed to itself.

This is accomplished with a kernel configuration command called ***sysctl***.

```
# sysctl -w net.ipv4.ip_forward=1
```

However, there is another important setting: mint01 must be made to send packets destined for mint03 in the direction of mint02, not in the direction of the Internet (up direction in Figure 4). This is a work instruction to make mint01 realize that intnet23 will be on the other side of mint02. In other words, there are routers on the Internet, which are network devices that forward packets destined to destinations other than themselves, and both hosts and routers have knowledge of which direction packets should be sent in depending on the destination, which is set in each network device. The mint01and mint03 become to enable to communicate each other after these operations in Figure 6.

Ex5) Start nginx on mint03 and Access from mint01. Watch access log on the server and confirm IP address of the client.

Start nginx, the http server, on mint03(Figure 7). Then, confirm that it can be accessed from the browser of mint01. If the training is for engineers, it is important for them to understand how to start applications and the meaning of configuration files. However, in training for non-engineers, the objective of the course is not equipment operation. For exercises at the police academy, it is important to be able to read log files. In the exercise, the location of the nginx log file for mint03 and the IP address of the access source are confirmed. The access source IP address is mint01, where the browser is running, and it is understood that it is possible to determine who writes to S N S and so on from that IP address.

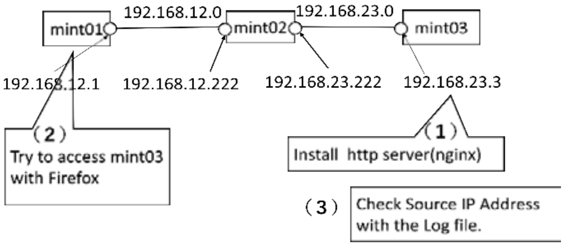


Fig.7 start nginx on mint03

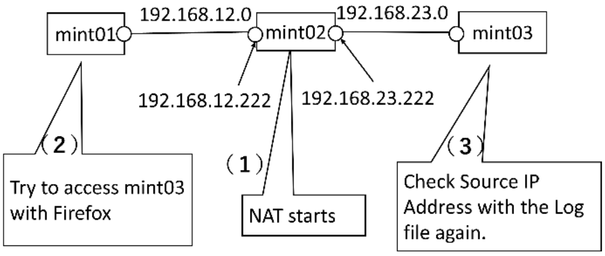


Fig.8 NAT on mint02

Ex6) Start NAT (ufw) on mint02. How does the Client The following section describes training materials designed to teach the skills necessary for first response to a criminal investigation.

Activate NAT on mint02 (Figure 8). NAT is used for security and to prevent IP address exhaustion in homes and by some cell phone companies. The following snippet has to be added in /etc/ufw/before.rules

```
*nat
-F
:POSTROUTING ACCEPT [0:0]
-A POSTROUTING -s 192.168.12.0/24 -o enp0s9
-j MASQUERADE
COMMIT
```

This rule is placed in mint02 from the beginning, and students can start NAT by simply submitting the following command.

```
root@mint02:~# ufw enable
```

After NAT is started, it is important to check that the access log in mint03 has changed to mint02. The IP address in the log is not necessarily the address of the writer's computer. Learn that a steady investigation to find the true source of the message is necessary, using the IP address in the log as a clue.

Ex7) Start Squid (HTTP Proxy) on mint02 and Change proxy settings of the client browser. What difference logs between NAT and Proxy in access log on mint02?

Activate HTTP Proxy instead of NAT on mint02 (Figure 9). A firewall similar to NAT is the HTTP proxy, which is used by public facilities and stores that provide Internet access services. The Squid server used in this course is an HTTP proxy server application with a long history; it differs from NAT in that all HTTP requests pass through an HTTP proxy. For this reason, the IP address of the HTTP proxy server must be set in the mint01 browser.

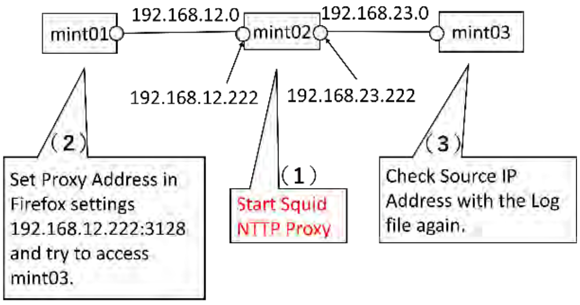


Fig.9 Start HTTP Proxy (squid) instead NAT on mint02

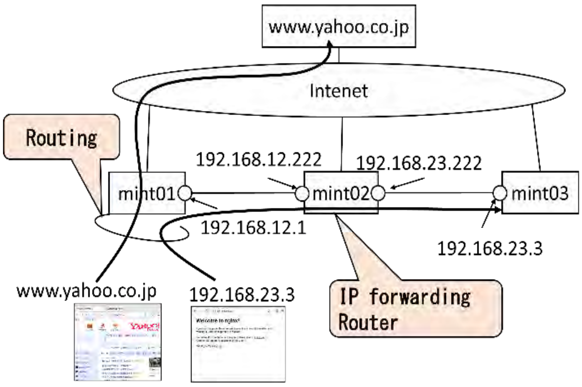


Fig.10 Separated Routes of packets before install HTTP Proxy

Unlike when mint02 is under NAT (Figure 10), when the HTTP proxy is activated, a record of what URLs mint01 has accessed is kept (Figure 11). It is necessary to understand where and what kind of content may be left in the access history, depending on whether it is NAT or HTTP proxy.

Ex8) Start nginx as Reverse Proxy on mint02 and eliminate proxy settings of the client browser. What difference of logs between Proxy and Reverse Proxy.

HTTP proxy are placed near access terminals such as public facilities and stores. On the other hand, HTTP

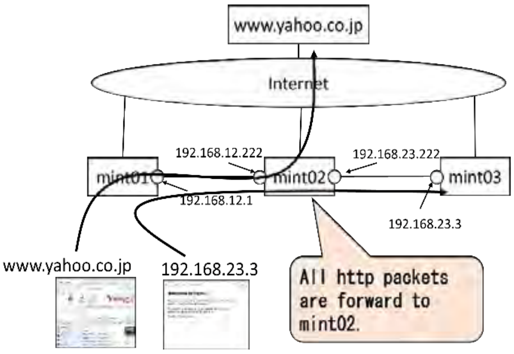


Fig.11 All HTTP Request packets are transmitted to mint02 after install HTTP Proxy

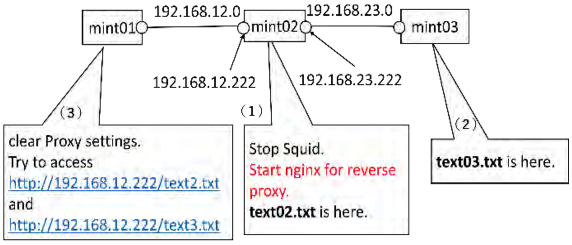


Fig.12 Start HTTP Reverse Proxy (nginx) instead squid on mint02

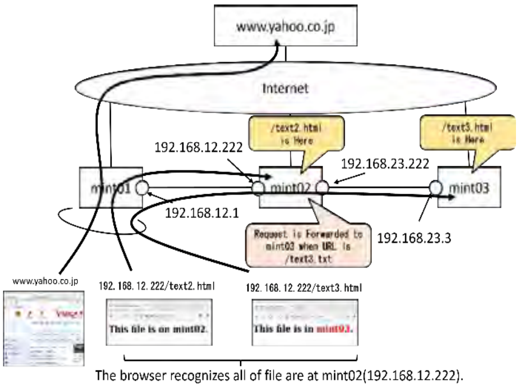


Fig.13 mint02 relays HTTP request to mint03 depending on URLs

This file is in mint03.

This file is on mint02.

Fig.14 http://mint02/text03.txt is on mint03

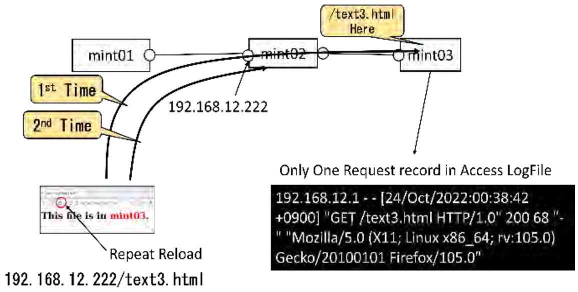
reverse proxies are placed near servers such as data centers and cloud services. Activate HTTP Proxy instead of HTTP proxy on mint02 (Figure 12). A reverse proxy acts as a load balancer or an accelerator. The mint02 reverse proxy will act as proxy of mint03 shown by Figure 13. The domain name (or IP address) of mint02 to be entered in the U R L window of mint01's browser. All HTTP request packets are received on mint02 and some packets are relayed to mint03. Figure.14 shows a couple of access requests of text content with different URLs.
http://mint02/text03.txt
http://mint02/text02.txt
One shows a text file in mint02 and the other in mint03.

Ex9) Activate cache features of the reverse proxy. What difference of logs on mint03 after that?

Enable the cache function of the HTTP reverse proxy (Figure 15). text03.txt is located only in mint03, so the first access will forward the request to mint03g. However, on the second access, the cache generated in mint02 will respond. Therefore, only the first access record remains in mint03.

6.Practice

These materials were really used in a class for acquiring networking skills for police officers at a police academy where the author serves as an instructor, using a pair programming method in which pairs are formed and hands-on practice is conducted. One person performs a task while the partner watches and provides advice. When one task was completed, the operator was switched. This allowed the participants to average out the differences in level to some extent and complete the nine exercises within the time allotted. The goal set in Chapter 3 are considered satisfactory.



```
192.168.12.1 - - [24/Oct/2022:00:38:42
+0900] "GET /text3.html HTTP/1.0" 200 68 "-
" "Mozilla/5.0 (X11; Linux x86_64; rv:105.0)
Gecko/20100101 Firefox/105.0"
```

Fig.15 Activate Cache function. The Second request would not be replied to mint03.

7.Conclusions

The following were the findings of the actual course, which was an exercise originally designed to train engineers, but adapted for police academies.

- ✓ Exercises using VM do not require actual routers or servers to confirm functionality.
- ✓ Even a commercial-class PC can run three Linux machines simultaneously.
- ✓ All Linux machines can be operated from a single screen on a single PC rather than using actual machines. This simplicity of operation is beneficial for non-engineers who do not need to handle actual equipment.
- ✓ By installing the applications and configuration files necessary for the exercises on Linux in advance, the exercises were not delayed by misconfigurations. Non-engineers do not need troubleshooting skills.

Non-engineers have different reasons for having to learn technology than do engineers. The conclusion is that the materials created for training engineers are not necessarily suited to the needs of non-engineers, even if they are used as they are in a course designed for non-engineers. They need to be reworked to meet the needs of the students. In the future, there will be an increasing number of situations in which non-engineers will need to learn network technology. It will be necessary to adapt the course materials accordingly.

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OCCUPATIONAL HYGIENE MONITORING USING PROJECT BASED LEARNING (PBL) APPROACH

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Abstract

Occupational safety and health (OSH) is an indispensable area across different careers. More and more employers and employees are concerning about their work safety and health and therefore requires high demand of labour entering the OSH industry. Relevant trainings on potential students would become important. The first critical criteria of establishing a safe and health work environment would be accomplished by workplace hygiene monitoring. By closely monitoring the workplace environment, this could reduce the risk of exposing employees to potential hazardous source. The continuous monitoring may include indoor air quality assessment, ergonomic assessment, physical and chemical risk assessment at the workplace. Students could acquire these practical skills through student initiative project-based learning (PBL). Many previous studies showed that practical learning, hands-on activities, and student activism help them to grasp the difficult technological knowledge and hence develop their intellectual processes. As different workplaces may have different scenarios, project-based learning provide an opportunity to let students to work on driving questions to simulate different work environment. Several workplace scenarios will be provided to students and they could work on the topics they are interested in. Then, fundamental workplace hygiene monitoring skills were introduced. Students are required to submit a proposal on the topics selected and they may have hand-on practice on using those monitoring equipment such as VOC and formaldehyde monitor, particle counter, heat stress monitor, sound level meter, etc. Students may discuss among themselves on sampling and measurement strategy, data processing and utilization. Learning progress of students is closely monitored through a series of activities including brainstorming, interview, industrial visit, etc. Instructors would then give the appropriate feedbacks based on student performances from each activity. The overall learning outcomes would be evaluated by final presentation and a poster session. Positive feedbacks from different stakeholders received using project based learning approach. The feedbacks obtained will be used to improve the learning and teaching quality in the next cycle.

Keywords: *Occupational safety and health, workplace hygiene monitoring, project-based learning, safety promotion, student initiative*

Introduction

In 2022, the total number of occupational injuries in all workplaces in Hong Kong was reported as 32,026 and the number of deaths was as high as 266 (HKLD, 2022). To prevent occupational injuries and accidents from occurring, occupational safety and health (OSH) is an indispensable area across different industries. Therefore, workplace safety plays an important role in any industry since workers are desire and willing to work in a safe and sound environment. OSH is always a relevant issue among different sectors as workers are at greater risk of work-related health causes and workplace accidents (European Agency for Safety and Health at Work, Web). From World Health and Organization (WHO), OSH is a multidisciplinary activity with the aim to protect and promote the health of workers by taking precautions against occupational accidents and diseases; and to develop and promote healthy and safe work, work environment, and work organizations (International, 2013). Occupational hygiene involves the use of instrument for the measurement of work-related parameters such as noise, heat stress, air and vapor concentrations, etc. Continuous occupational hygiene monitoring therefore provides a scientific basis to improve the workplace safety. The continuous monitoring may include indoor air quality assessment, ergonomic assessment, physical and chemical risk assessment at various workplaces.

Since occupational hygiene monitoring requires scientific approach, in-depth student trainings and guidance such as sampling strategies, equipment instrumentation and data analysis are necessary. Project based learning (PBL) approach would be the most suitable way to provide an opportunity to let students to work on driving questions to simulate different work environment as different workplaces may have different scenarios. PBL is a learning approach during the entire learning process of students. Students could obtain knowledge through a project with a driving question proposed by the teacher. Students need to actively search information and resources by themselves to solve the problems. Recent studies have found that students can learn and improve scientific practices with guidance (van der Graaf et al., 2015). This approach allows students in asking scientific questions and conducting investigations such as collecting information from different sources, doing experiments, and making observations to solve the authentic problems and is therefore considered effective in encouraging students to develop and apply skills and knowledge (Krajcik & Czerniak, 2018). Due to the complexity in design, PBL usually takes the form of group projects (Montequín et al., 2012), which allows students to learn through communication and cooperation skills and a necessary soft skill to work successfully in the future.

The aims of this study are to (1) promote the occupational safety awareness via students' trainings; (2) introduce a series of students' trainings on occupational hygiene monitoring by project-based learning approach and (3) evaluate the effectiveness of integrating project-based learning into teaching and learning.

Materials and Methods

At the beginning of the course, students were given a PBL project brief comprising of the project title, driving question, project objective, project structure, roles and responsibilities, project path and milestones, assessment rubrics, professional ethics and safety precaution. Students were divided into groups of 4 to 5 and they worked on the same project theme '*Formulation and Implementation of Occupational Hygiene Assessment for a Workplace*' and shared the same driving question '*How do we develop and implement a suitable and effective occupational hygiene assessment for a workplace in order to ensure the safety and health of all employees at work?*'. A two-hour lesson was constructed for students to discuss and brainstorm the topic with guidance given by teacher meanwhile. During the lesson, teacher requested students to propose some authentic workplace environment which requires in-depth hygiene monitoring. An interactive and student-led learning atmosphere were established during lesson.

Based on the feasible ideas obtained from the discussion session, students were required to complete a proposal. Several possible workplace scenarios with available monitoring instrument were given to students to choose from (Table 1). Students had to match the suitable instrument with workplace scenarios. The proposal required students to provide background information, sampling and measurement plan and brief working principle of selected instrument. At the same time, teacher had given a brief lesson on sampling strategies and theory and operation of instruments. For example, heat stress monitor and sound level meter quantify wet-bulb globe temperature (WBGT) and workplace noise level respectively. Anemometer measures the flowrate of hoods or ducts which reflect their efficiency. Formaldehyde meter and TVOC meter provide useful parameters for monitoring the indoor air quality (IAQ). These workplace scenarios and instrument were chosen because they could truly reflect the needs of hygiene monitoring for the industry in Hong Kong.

Table 1. Choices of workplace scenarios and available monitoring instrument.

Possible Workplace Scenarios	Available Instruments
1. A chemical testing laboratory with several fume hoods in operation. 2. Indoor & outdoor areas where several steam generators in operation. 3. A factory where several heavy manufacturing machineries in operation. 4. An indoor space where painting work using latex paint and thinner in operation. 5. A manufacturing area where production of adhesives of furniture in operation	1. Heat Stress Monitor 2. Anemometer 3. Formaldehyde Meter 4. Sound Level Meter 5. TVOC Meter

Meanwhile, teacher arranged five practical sessions to familiarize students with the scenarios listed in Table 1 and allowed them to have a hand-on experience in operating the instrument. During the session, students worked in group to think of the measurement flow. The problem-solving skills resembles the steps of scientific research and involves a research approach (Sari et al., 2019; Tambunan, 2019). After each session, students needed to hand in a report summarizing the findings and data treatment. This simulated the workplace assessment report across the industry.

The performance of students was closely monitored by continuous assessment and end of semester assessment. Continuous assessment includes group progress assessment evaluated by the teacher on collaboration skills, responsibility skills and communication skills. End of semester assessment includes student demonstration on the operation of instrument and data treatment and analysis. Students will be assessed based on their technical skills such as instrumental preparation, sampling techniques and data analysis.

Finally, students were required to complete a feedback and reflective journal. A simple questionnaire was sent to industry partner for their feedbacks.

Results and Discussion

The learning effectiveness of PBL approach on occupational hygiene monitoring was evaluated by comparing student performance before and after adopting PBL. After using PBL approach, students showed significant improvement on final practical demonstration. Without using PBL approach, students reported difficulties in understanding the complicated concepts and instrumentation of the monitoring equipment, and therefore in the past the mean score in all assessments was not very high. After the adoption of PBL approach, a significant improvement of student's mean score was observed. Through PBL, students could know the theory of different occupational hygiene monitoring techniques. For example, heat stress appears when heat gain is greater than heat loss, inducing a loss of homeostasis and an increase in body temperature (Most and Yates, 2021), finally may cause heat stroke for prolonged exposure. Prolonged exposure to high noise level may cause sensorineural loss, damaging the hair cells in cochlea. Students are especially required to measure the workplace noise levels for certain work process in the future such as grinding, pile driving, etc. In Hong Kong, it is mandatory by the Labour Department to carry out noise assessment at the construction sites. Therefore, students should learn to operate the sound level meter and the related theory behind. Besides, excessive exposure to formaldehyde and volatile organic compounds (VOCs) may cause irritation in lung airways and even carcinogenic (Pappas et al., 2000). Sources of exposing formaldehyde and VOCs include oil painting, releasing from furniture and carpet, etc. Indoor workplace air quality assessment can protect workers' health. Occupational hygiene monitoring provides an alternative way to safeguard the health of workers and reduce the number of occupational injuries, thus promoting the public awareness of occupational safety.

For students' feedback, the majority satisfied with the process and outcomes of PBL, and the skills obtained are useful in their future career, however, some students reflected the difficulties in searching information, planning and writing of the proposal. All students agreed the adoption of PBL approach in occupational hygiene monitoring could effectively help to understand the concepts and instrumental operation theories. Improved performance on practical skill test confirmed the acquisition of the lifelong skills. For feedback from industry partner, they agreed that the PBL contents are very related to real world situation and industry linked. They also reported it was not difficult to understand what must be done in PBL project. Overall, industry partner was satisfied with the performance of the project aims and outcomes.

PBL is a learner-cantered approach which engages students in deeper learning by empowering them to learn more related content and various skills in authentic contexts. It was observed from this PBL that it emphasizes on putting students at the centre and highlighting students' independent experience, teachers' roles also shift from more dominating to more facilitating roles. Wang (2022) also pointed out that adopting PBL leads to benefits such as supporting students acquiring content knowledge as well as cultivating students' cooperation and team spirit. From the classroom observation, teacher discovered that students were eager to raise questions regarding the technical skills. The learning atmosphere was also improved since students became a key role throughout the whole learning process. Besides, students were able to apply what they read and analyse the workplace scenarios in connection with what happened in the real world. Therefore, PBL can be used as an effective approach to develop students' critical thinking development which is an essential soft skill in their future work.

Conclusions

It can be observed from this study that the original complicated theory of occupational hygiene monitoring could have a better understanding towards students using PBL approach. Students showed significant improvement in their assessment results. At the same time, both students and industry partner welcomed and showed positive feedbacks with the adoption of PBL approach in learning occupational hygiene monitoring. Since occupational hygiene monitoring is an indispensable aspect of OSH in Hong Kong, cultivating the motivation of students' learning in this area can therefore promote the awareness of occupational safety among them. It is therefore suggested the adoption of PBL learning in other modules to facilitate the classroom learning atmosphere, especially for some difficult-to-understand concepts.

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Examination of Incorporating Elements of Career Education and Financial Education in Engineering Courses to Encourage Continuous Introspection

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Abstract

For students to function independently after graduation and begin a financially stable life, they need to acquire financial literacy while still in school, using their own motivation, money, and time to invest in them. KOSEN provides many opportunities to demonstrate the achievements that have resulted from their self-investment, such as robot contests. However, many students who do not voluntarily take advantage of such opportunities tend to lose their awareness of the importance of learning, as they prioritize their immediate assignments and exams. In this study, we discussed a method that incorporates elements of career education and financial education in specialized subjects for to promote introspection among students and raising the profile of awareness of self-investment. We also created a prototype for teaching materials to be applied to electrical subjects in the lower grades and examined its validity.

If students are to develop introspection, they must first of all have a clear reason for studying at school. Self-analysis is effective for this practice. Furthermore, to enable them to live a rich life without worrying about money, after providing concrete lectures on general matters of financial planning during their studies and after graduation, students should be asked to describe their own lives and career policies. While they are provided with the knowledge and opportunity to reflect on the outcomes of their continuous introspection, students take on specialized subjects that are intended to produce for the financial literacy that forms the basis of financial planning. Career and financial literacy encourage students' independence and motivation to study specialized subjects at every time that they interact with money in their daily lives.

The motivation for learning and for career and financial literacy cannot be obtained overnight, so this initiative cannot be a one-time class but must continue to develop. For an example of a specialized subject class that incorporates elements of career education and financial education, we created a prototype of a solar cell power generation investment teaching model for second-year students' study of electromagnetism. In a post-lesson questionnaire, 47% of students who took classes using this teaching material gave positive evaluations, and 12% of them gave negative ones. To increase the number of positive evaluations, it is necessary to improve the lesson further, such as by adjusting the difficulty level.

Keywords: *career education, financial education, engineering education, incorporating elements of education, self-investment*

Introduction

The "White Paper on Children and Young People" published by the Cabinet Office of Japan (2014) indicates that young people in Japan have strong concerns about working. Take a familiar example: before a fourth year KOSEN student participates in a weeklong internship, he or she is likely to ask careless questions, such as, "Can you recommend a suitable company?" Ideally, applicants should apply only after assessing their own interest in the company's business and operations based on the values that they have acquired. This is due to the lack of active involvement from instruction in specialized subjects regarding career knowledge (way of life, sense of values, etc.) that serves as a bridge between curricular classes, consisting of the liberal arts and specialized subjects, and extracurricular activities, which can be a means of expressing learning outcomes. This is considered an important factor. If there is little active involvement from instructors in specialized subjects, the students are not encouraged to reflect deeply on the significance of their studies, and it may be difficult for them to improve their motivation for their activities. Career knowledge, such as that which regards the student's own way of life and sense of values, accumulates in multiple layers by means to daily reflection and stimulation from aspects of the external environment, such as family, school, and community; by this means, a sense of self-affirmation is fostered. However, if little self-affirmation is accumulated during the enrollment period, a strong tendency to be caught by external factors appears, such as low test scores, and the motivation to study specialized subjects decreases. The homeroom teacher generally deals with such student problems. However, it is difficult to provide detailed guidance to dozens of students. To deal with such situations, it is necessary to have on hand teaching materials and practice classes that can encourage students to reflect on them.

In our studies so far, we have sought to positively associate specialized subjects with students' career development, targeting KOSEN students who are applicants and observing the effects. Examples of such programs include investigative studies in groups, using factory tours, guided physics experiments for junior students performed by senior student facilitators, and self-analysis guidance, using overseas study and training applications. However, these practices have not been sufficiently effective in promoting strong introspection.

In this study, therefore, we have determined that students will be able to think about the money that they require in their life plans after graduating from KOSEN, as well as the careers that they will need as engineers. Moreover, we have encouraged students to pursue introspection and the study of their subjects. By this means, we examined the effects of teaching materials and classes to increase the awareness of investment to allow the students to generate and improve their learning motivation. In this report, we discuss the method of incorporating elements of career education and financial education in specialized subject classes, which is important for the practice of this education and the validity of prototype teaching materials.

Materials and Methods or pedagogy

Figure 1 presents a conceptual diagram of the expected effects of incorporating elements of career education and financial education in specialized subject education. Students can advance their studies by igniting the fire of learning motivation on the firewood of their specialized subjects and liberal arts subjects. Here, those students who can set their learning goals and maintain their motivation for learning can continue to learn autonomously. However, because students do not have strong introspection, it is necessary to develop strong learning motivation and continuous education for introspection. This education forms the approach implemented in this study. Through specialized subject education that incorporates career education and financial education, students can develop self-analysis skills, financial literacy, the ability to apply their specialized knowledge, and strong continuous introspection, asking themselves "How do I want to live? What do I want to do?" and "Do you want to cherish it?" These students develop the self-investment consciousness that if they continue to study specialized subjects, they can make money and increase it. Students who continuously and deeply reflect will, through extracurricular activities that are a means of expressing their learning achievements, be well prepared for a fulfilling career after graduation.

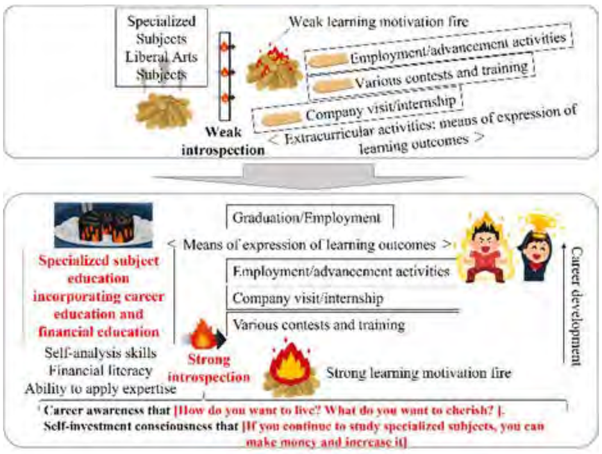


Fig. 1. Conceptual diagram of the effect of this initiative.

Table 1. List of elements of career education and financial education incorporated into specialized subject education.

Table 1 presents the elements of career education and financial education that are to be incorporated into specialized subjects, together with the attainment goals for each element. The elements of career education are self-analysis, career planning and life planning. The elements of financial education are investment concepts, inflation/deflation, compound interest, discounted present value, and risk/return. The acquisition of this financial knowledge will enable students to understand that self-investment for professional knowledge and skills development can be expected to generate stable and high returns over the long term with low risk, making it a superior investment to financial products. The results of self-analyses written by students are to be included the specific goals and dreams of KOSEN students on their way to becoming engineers, based on their financial literacy.

The requirements for specialized subject learning content that is suitable for incorporating elements can be listed as follows: 1) there should be something to study that is close to students, 2) the students should be able to apply their specialized knowledge, 3) there should be elements related to resolving social issues, and 4) the investment targets should be general and familiar to students. The fact that there are learning objects that are close to the students and that they are common investment targets is intended to deepen students' interest through news and other sources.

In addition, through incorporating the solution of social issues, we hope to broaden student horizons by touching on the liberal arts content engineers should know. Being able to apply specialized knowledge to a problem among an engineer's most important skills.

The teaching materials consist of textbook descriptions of each element of career education and financial education, the slides used in specialized subject classes, and the devices for practical training that students use during classes. The textbook is intended to enhance learning effects in class through requiring readings of it before class in specialized subjects. The practical equipment uses the Raspberry Pi 4B, an embedded microcomputer board, including the elements of a control equipment system called sensors and actuators. These are intended to be used as teaching materials that meet the goals of the students taking the classes, as the courses that the students are taking are those on electronic controls and information systems.

Results and Discussion

Table 2 presents the specific content of the classes discussed in the methods section. The classes are held across multiple grades through adjusting the specialization of the goal in electrical and electronic subjects that can handle solar cells, such as electromagnetism (second-year), sensor engineering (fourth year), and electronic devices (fifth year). In this way, students are encouraged to reflect continuously. In this report, electromagnetism classes go for 90 minutes for a total of five classes. The first week covers the electrical basics to present the principles of solar cells. The electrical fundamentals course primarily with Ohm's law and the units of power and energy. During the second week, we dealt with career cases after graduating from KOSEN, self-analysis methods, and life and career planning to indicate the importance and methods of setting a long term career course. In the third week, we dealt with the concepts of investment and concrete financial literacy, such as inflation/deflation, compound interest, discounted present value, and diversified investment, to clarify the ways that money increases over time and understand economic rationality. During the fourth week, after identifying the principles of power generation from solar cells, students practiced calculating the yield on investment in solar power generation, and had students discuss how to increase the value. In the fifth week, which is the final week, we presented content on self-investment and had them perform self-analysis.

Table 2. specific contents of the classes discussed in the methods section.

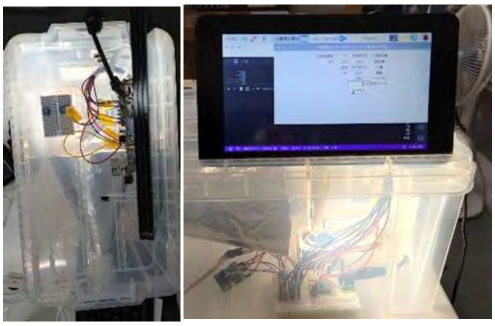


Fig. 2. Solar power generation investment teaching materials used for practical training.

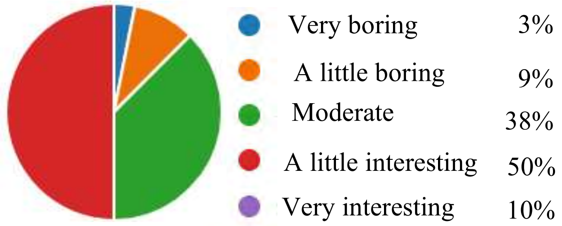
Figure 2 shows the teaching materials used in this training. The current, voltage, power, and temperature of the solar cell can be measured while irradiating the solar cell with a light-emitting diode. In addition, the solar cell can be tilted using a stepping motor to simulate the change in power generation owing to the tilt angle of the sunlight. These operations can be performed with a touch panel connected to a Raspberry Pi 4B. In the final week, the fifth week, after studying the importance of self-investment in relation to one's career and financial literacy, students were asked to conduct a self-analysis including activities for self-investment.

Table 3 presents responses to a questionnaire regarding the necessity of career and financial education for second-year KOSEN students. In response to question 1, "If I get a job, I will use the specialized knowledge and skills I learned at KOSEN (or university) in my work," 70% provided a positive response (4 or 5 points), and 7% provided a negative response. KOSEN is an educational institution created to nurture specialists, so responses should be uniformly positive. In response to item 2, "Studying specialized subjects is fun (rewarding and motivating)," only 42% provided a positive response. It is necessary to improve students' ability to find classes in their specialized subjects interesting. Item 3 was, "I have a desire to study hard in order to get a job, earn money, and lead a prosperous life in the future." As with item 1, this item received many positive responses. This implied that a certain number of students wanted to do their best in their studies, even though their specialized subjects were not very interesting. Item 4 was "It is important to save and increase money in order to lead a fulfilling life," to which 88% responded in the affirmative. It was implied that most students had sufficient grounding to

Table 3. Answers to a questionnaire on the necessity of career and financial education for second-year technical college students.

Q1. How interesting was the career/finance class?

Q2. How interesting was the class about principle of solar cell?



Q3. How interesting was the solar investment yield game training?

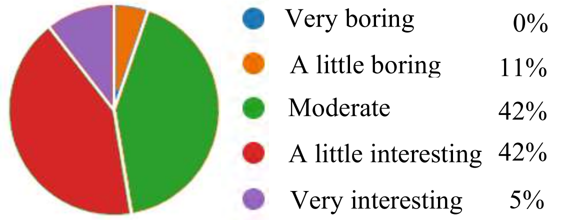


Fig. 3. Responses to a questionnaire to evaluate initiative validity by second-year electromagnetism students.

accept financial education. From these responses, it appears that financial education for these technical college students was of high importance.

Figure 3 presents the results of the student questionnaire by a second-year electromagnetism class to evaluate the validity of this initiative. Question 1 was “How interesting was the career/finance class?” The response from 59% of students was that it was interesting. It appears that a majority of the students viewed career and financial education positively. Question 2 was "How interesting was the class on the principle of the solar cell?” Here, 60% of the students evaluated this class as interesting, at about the same level as question 1. Because it incorporated elements of career education into financial education, the class on the principles of solar cells may have seemed fresh to the students. Question 3 asked “How interesting was the solar investment yield game training?” Of the total group of students, 47% rated it as interesting. This was a significantly lower value than those for questions 1 and 2. Because in this practical training, the students calculated the yield of solar power generation after a narrowly focused explanation, the instruction may not have been interesting for the students. Thus, it is necessary to incorporate more ideas to promote active student involvement in classes, such as in the selection and concentration of class contents and improved playability.

Conclusions

This report presents some means of incorporating elements of career education and financial education into specialized subject education, the expected effects, and the attainment of students’ goals. We also described the teaching materials for use in this activity and their aims. In line with this initiative presented a trial cause of a class in electromagnetism for second-year students). The student questionnaire, administered after five weeks of classes, showed that students require career education and financial education. It was also confirmed that students had a low sense of affirmation in their study of specialized subjects. Many students provided a positive evaluation of the elements of career education and financial education through their evaluation of the validity of the lessons presented through this initiative. However, the solar power generation yield game practice, which connects specialized subject education and financial education, received poor evaluations, indicating the need for a device to encourage students to participate actively in class.

Acknowledgements

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PRACTICE OF INTELLECTUAL PROPERTY CREATION EDUCATION USING THE TONGS MODEL OF OTSM-TRIZ

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Abstract

National Institute of Technology, Numazu College established a club activity IP-TKY (Intellectual Property Terakoya) with the aim of future industrial human resources who will be responsible for Society 5.0 by using TRIZ. In particular, Tongs Model of OTSM-TRIZ, which fosters solutions to technical problems by understanding the ideal and reality and clarifying the difference between them, is practiced.

As practical examples, (1) Challenging Ene-1 GP which is the battery bicycle (KV-BIKE) race powered by 40 rechargeable AA batteries held at the International Racing Course in Suzuka Circuit and Mobility Resort Motegi. (2) Observation of deep-sea creatures and topography by shooting deep-sea images of Suruga Bay, the deepest bay in Japan. (3) To study the TRIZ's 40 principle of invention, making a life-size model of coelacanth using educational 3D blocks (Artec block) to exhibit in Numazu bay deep sea aquarium. (4) Challenge the patent contests.

These activities were highly evaluated and were introduced at the commemorative event of World Intellectual Property Day (April 26,2022) of WIPO (World Intellectual Property Organization) Japan office. Furthermore, in collaboration with Suruga Bay Ferry, we produced a video introducing the charm of Suruga Bay by Riz Chitera, an original Vtuber related to intellectual property, and developed 3D model education materials to study deep sea topography. In that activity, we tried to solve technical contradictions using the TRIZ's inventive principles. We created a Suruga Bay educational program and held a Suruga Bay classroom for elementary and junior high school students at the Suruga Bay ferry and Izu Shirakabeso in order to revitalize the region, a new tourism model was created that added the value of intellectual property education to conventional tourism such as transportation and accommodation by practicing intellectual property creation education using the Tongs model of OTSM-TRIZ.

Keywords:*TRIZ, OTSM, TONGS model, Problem Solving Intellectual Property, Creation Education, Izu, Suruga Bay, IP-TKY*

Introduction

In 2016, National Institute of Technology, Numazu College established a club activity IP-TKY (Intellectual Property Terakoya) with the aim of developing value-creating future industrial human resources who will be responsible for Society 5.0 by using TRIZ. TRIZ is an idea conception method born from the analysis of 2.5 million patents, and includes problem-finding tools such as the 9-screen method and problem-solving tools such as TRIZ's 40 inventive principles. In particular, Tongs Model of OTSM-TRIZ, which fosters solutions to technical problems by understanding the ideal and reality and clarifying the difference between them, is practiced. The main activities are (1) Taking advantage of the regional characteristics of the mobility industry, we are challenging Ene-1 GP which is the battery bicycle (KV-BIKE) race powered by 40 rechargeable AA batteries held at the International Racing Course in Suzuka Circuit and Mobility Resort Motegi. And the activity has cooperation with environmental energy education. (2) Conducting deep sea research activities in Suruga Bay, which is the deepest bay in Japan (water depth 2,500m), we are taking advantage of its regional characteristics. And, the results of these activities are cooperated with the activities of local governments and companies. (3) As part of the development of education materials based on regional characteristics, we are conducting program robot classes using 3D blocks (Artec block) and TRIZ educational activities. In 2021, in making a life-size model of coelacanth using educational blocks, we tried to solve the technical contradiction of shape and strength using the TRIZ's inventive principles. These activities were highly evaluated and was introduced at the commemorative event of World Intellectual Property Day (April 26, 2022) of WIPO (World Intellectual Property Organization) Japan office. Furthermore, in collaboration with Suruga Bay Ferry, we produced a video introducing the charm of Suruga Bay by Riz Chitera, an original Vtuber related to intellectual property, and developed 3D model teaching materials to study deep sea topography. In that activity, we tried to solve technical contradictions using TRIZ's 40 principle of invention. We created a Suruga Bay educational program and held a Suruga Bay classroom for elementary and junior high school students at the Suruga Bay ferry and Izu Shirakabeso. In order to revitalize the region, a new tourism model was created by adding value to conventional tourism such as transportation and accommodation by practicing intellectual property creation education using the Tongs model of OTSM-TRIZ. Furthermore, we are challenging patent contests by making use of the creativity cultivated through these activities.

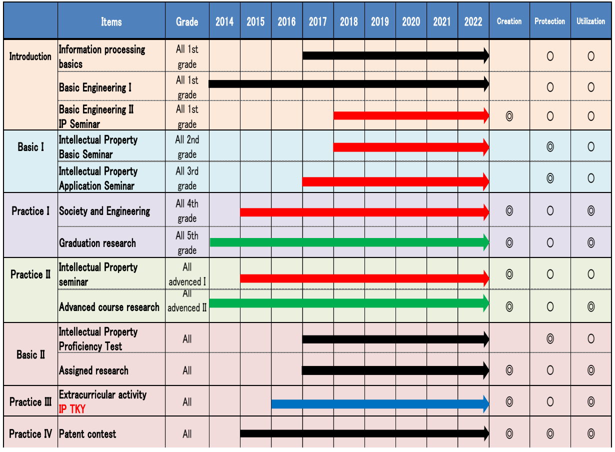
Educational Materials and Methods

Campus-wide intellectual property creation education

National Institute of Technology, Numazu College is located in the eastern part of Shizuoka Prefecture, close to the Tokyo metropolitan area, surrounded by the region's unique characteristics such as Japan's highest mountain, Mt. Fuji, Japan's deepest bay, and the Izu Peninsula Geopark, and opened as a 1st term school in 1961. There are five specialized departments: mechanical engineering, electrical and electronic engineering, electronic control engineering, control information engineering, and material engineering, as well as a comprehensive system engineering course, with approximately 1,050 students studying there (Figure. 1). The Department of Comprehensive System Engineering was established in 2012, and has three courses: Environmental Energy Engineering, New Functional Materials Engineering, and Medical and Welfare Equipment Development Engineering. Since 2009, as part of the "Pharma Valley Concept" promoted in the eastern part of Shizuoka Prefecture, our school has been responsible for human resource development in the medical equipment development engineer training program. In recent years, the Cabinet Office Intellectual Property Strategy Promotion Secretariat has been promoting intellectual property creation education in elementary, junior high, and senior high schools and technical colleges. In particular, INPIT (Industrial Property Information and Training Center) is promoting the "Development Project for Intellectual Property Creativity, Practical Ability, and Utilization Ability" for specialized high schools and technical colleges that will produce tomorrow's industrial human resources. Our school has been participating in this project since 2016, emphasizing intellectual property education from the perspective of developing local industries and developing human resources who will be responsible for Society 5.0. In order to promote intellectual property learning throughout the school, our school conducts a "spiral-up type" that continuously touches "intellectual property" according to the stage of growth at least once a year from first year students to advanced course students. A campus-wide intellectual property learning system has been constructed (Table 1). Since 2018, an intellectual property seminar has being held for all first-grade students by the teacher in charge. And in collaboration with the Japan Patent Attorneys Association, an intellectual property basic seminar for all second-grade students and an intellectual property application seminar for all third-grade students have being held. In addition, there is an intellectual property skills test and intellectual property learning through assignment research. Through these studies, all students' interest in intellectual property studies is increasing. Also, in the upper grades, in the compulsory subject "Society and Engineering" for all 4th grade students, we analyze the situation of local governments and companies a method of thinking about the problems found there using TRIZ as a weapon. We are conducting a curriculum that "proposes solution ideas that are conscious of utilization". The hierarchy of TRIZ education is shown in Figure 2. For students who want to learn more, there are assignment research and extracurricular activity "Intellectual property TKY".

Figure 1 NIT, Numazu College

Table 1 Campus-wide IP creation education



	Items	Grade	2014	2015	2016	2017	2018	2019	2020	2021	2022	Creation	Protection	Utilization
Introduction	Information processing basics	All 1st grade				→	→	→	→	→	→		○	○
	Basic Engineering I	All 1st grade	→	→	→	→	→	→	→	→	→		○	○
	Basic Engineering II IP Seminar	All 1st grade					→	→	→	→	→	◎	○	○
Basic I	Intellectual Property Basic Seminar	All 2nd grade					→	→	→	→	→		◎	○
	Intellectual Property Application Seminar	All 3rd grade				→	→	→	→	→	→		◎	○
Practice I	Society and Engineering	All 4th grade		→	→	→	→	→	→	→	→	◎	○	◎
	Graduation research	All 5th grade	→	→	→	→	→	→	→	→	→	◎	○	◎
Practice II	Intellectual Property seminar	All advenced I		→	→	→	→	→	→	→	→	◎	○	○
	Advanced course research	All advenced II	→	→	→	→	→	→	→	→	→	◎	○	◎
Basic II	Intellectual Property Proficiency Test	All				→	→	→	→	→	→		◎	○
	Assigned research	All				→	→	→	→	→	→	◎	○	◎
Practice III	Extracurricular activity IP TKY	All			→	→	→	→	→	→	→	◎	○	◎
Practice IV	Patent contest	All		→	→	→	→	→	→	→	→	◎	◎	◎

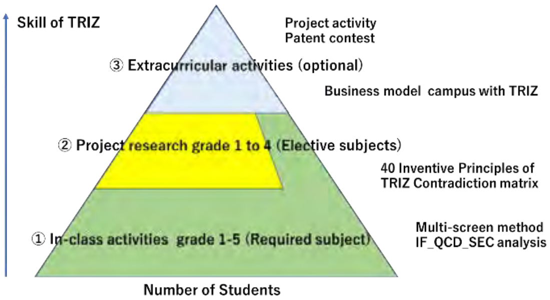


Figure 2 Contents of TRIZ education

Intellectual property TKY

In 2016, a special club as an extracurricular activity, "Intellectual Property TKY (Terakoya)" was established with the aim of developing value-creating future industry human resources who will be responsible for Society 5.0. Raise interest in intellectual property, analyze regional characteristics, and conduct intellectual property activities aimed at utilizing those regional characteristics as one's own business. It has regional characteristics represented by Mt. Fuji and Suruga Bay, and conducts activities in collaboration with local governments such as environment, energy, nature conservation, agriculture, fisheries, and tourism. In particular, through the challenge to the real thing, we aim to understand the difference between the ideal and the reality, and to practice the TRIZ Tongs model to work on the solution. There are three main activities, the first is the battery bicycle race, the second is the Suruga Bay deep sea survey, and the third is the development the education materials to learn the TRIZ and to create the added value. The KV-BIKE project utilizes the regional characteristics of the mobility industry, and uses 40 rechargeable AA batteries to compete in the Suzuka Circuit International Racing Course and the Twin Ring Motegi Super Speedway challenge and cooperation with local environment and energy education. The deep sea project is in collaborating with local governments and companies that make use of the deep sea survey activities of Suruga Bay, which makes use of the regional characteristics of Japan's deepest bay (2,500 m deep), and the contents of the survey. The education material development project is developing of 3D blocks with the theme of regional characteristics and developing of education materials to learn the TRIZ and to create the added value that make use of regional characteristics. In addition, using the creativity nurtured through these activities, we are also challenging patent contests.

(1) KV-BIKE project

In the KV-BIKE Project, a battery-powered bicycle race, battery-powered bicycles equipped with 40 rechargeable AA batteries compete for a time attack over a course of about 2km and a total of points earned in a 1-hour endurance race. This battery-powered bicycle race takes advantage of regional characteristics and is used as educational materials for futuristic electric mobility and environmental energy education (Figure 3). Our school challenged the international racing course of Suzuka Circuit and the Twin Ring Motegi Super Speedway as a battery bicycle race. Energy management is the key to victory, and along with this, various ingenuity is required. For example, the position and angle of the saddle are adjusted so that the body is in a straight line to reduce air resistance. In 2021 and 2022, it has been selected as one of the 4 KV-BIKEs whose driving posture seems to be unduly tight.

(2) Deep Sea Project

Suruga Bay has a depth of 2,500 m. In Figure 4, the roadmap of our deep sea survey is shown. We developed a real-time monitoring system (DREAM_1) in 2016, reaching a depth of 100 m. After that, the first 4K video shooting system (PIXY) was newly developed, and in 2018, it succeeded in shooting 4K video at depths of 530m and 1030m from the sea surface. In 2019, Our project (Figure 5) used the second system (PIXY-II) with improved water pressure resistance, and succeeded in 4K shooting at a depth of 1530m and in 2021 at a depth of 1750m. Furthermore, in 2022, we developed the third system (PIXY-MONA), which enables long-time recording by further improving the water pressure resistance of the light and increasing the battery, and succeeded in 4K shooting at a depth of 2030m.The results are announced at the Zoological Society of Japan after the dates have been confirmed at the notary public office (Figure 6).

Figure 3 KV-BIKE Project

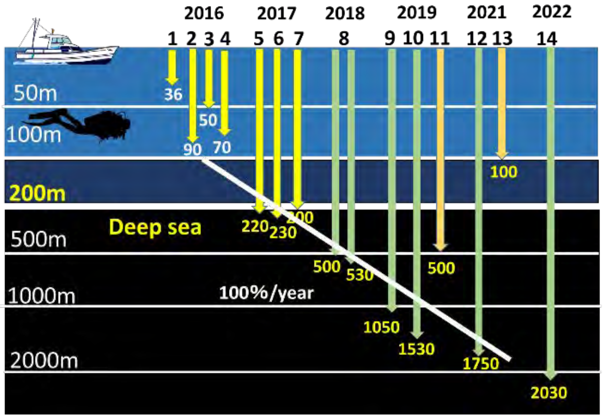


Figure 4 Deep sea survey road map

Figure 5 Deep sea project

Figure 6 Confirmation of date

(3) Educational material development project

In 2020, deep sea survey was restricted due to the impact of the corona disaster. Therefore, in order to express the charm of the deep sea, we decided to create a life-size model of the coelacanth, which is said to be the "fish that brings happiness" (Figure 7). In the first stage, it was designed with Microsoft's Minecraft (a 3D creation game), and then in the second stage, it was actually produced with 11,000 3D blocks (blocks for educational materials) from Artec. We wanted to freely shape what we thought, but we challenged the technical contradiction that strength is necessary with the TRIZ Inventive Principles, furthermore, we experienced practically that "value" is created in the work. The activities of this life-size 3D block model of the coelacanth were introduced at a commemorative event for World Intellectual Property Day of the World Intellectual Property Organization (WIPO) on April 26, 2022. The work was introduced at the LOVE NUMAZU event in Numazu City held at the commercial facility "Lalaport Numazu" in October 2020, and then exhibited at "Lalaport Numazu" for a month. From December 2020, it has been exhibited as the sixth coelacanth next to the real frozen coelacanth at the Numazu Deep Sea Aquarium. In addition, taking this opportunity, we are conducting research on the behavior observation of Bathynomus doederleinii with the Numazu Deep Sea Aquarium.


Figure 7 3D Block coelacanth


Figure 8 Observation of Bathynomus doederleinii

In collaboration with Suruga Bay Ferry, intellectual property Vtuber "Riz Chitera" produced a video introducing the charm of Suruga Bay. This is part of an on-board educational program that uses the results of the Suruga Bay deep sea survey efforts to convey the attractions of deep sea topography, deep sea creatures, and deep-sea heritage to elementary and junior high school students (Figure 9,10,11). In addition, as an educational material for Suruga Bay, we developed a Suruga Bay 3D model education material that can learn the topography of Suruga Bay. A technical contradiction during development, "It takes time (about 1 hour) to create the shape of Suruga Bay with a 3D printer. Also, we can't make a lot of them" was challenged using the TRIZ 40 Inventive Principles. Consider with TRIZ Contradiction Matrix. We want to" make it easy" to make", but it takes "hours". Consider solutions with TRIZ 40 Inventive Principles. Inventive principle 35: Principle of Parameters changes for liquid to solid, concentration, hardness and temperature. Inventive principle 28: Principle of Sensor utilization (replacement of mechanical method, another perception) for processing method. Inventive Principle 34: Principle of Exclusion regeneration for remove unnecessary parts. Inventive Principle 4: Asymmetry principle for make it easier to remove from the mold. As a result, create a reverse mold with a 3D printer, stamp it on clay, and create the shape of Suruga Bay. Figure 12 shows various prototypes, Table 2 shows the prototype results, and Figure 13 shows the relationship between ease of production and time. In particular, in response to a request from the Suruga Bay Ferry that they wanted to implement it in 10 minutes, as a result of examining Figure14, it was decided to use a case direct insertion type in Figure15. We created a Suruga Bay educational program and held a Suruga Bay classroom for elementary and junior high school students at the Suruga Bay ferry and Izu Shirakabeso in Figure 17 and 18.

Figure 9 Suruga Bay educational video

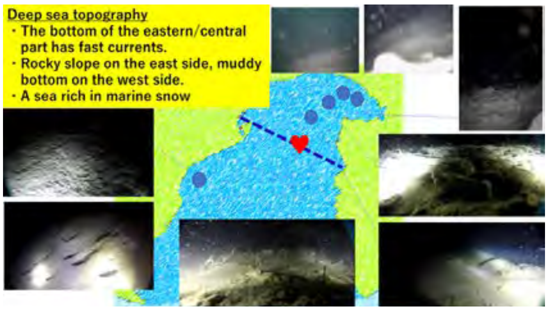

Deep sea topography
- The bottom of the eastern/central part has fast currents.
- Rocky slope on the east side, muddy bottom on the west side.
- A sea rich in marine snow

Figure 10 Deep sea topography

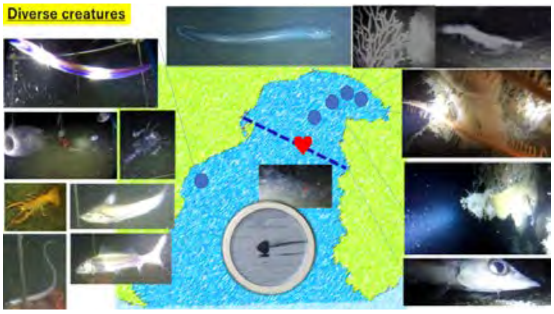


Figure 11 Deep sea creatures

Figure 12 Suruga Bay Topographical Model

Table 2 Suruga Bay Topographical Model

Type	No	Clay	Company	Quantity	Price		Drying		Remove		Works		Added value		Score
Resin	1	Natural drying	A	400g	¥480	○	not dry easily	X	Hard to remove	△	-	△			4
	2	Oven	D	45g	¥100	○	120℃ 15minutes	△	Hard to remove	△		○	Feel of a material	○	8
	3	Hotwater	D	-	¥200	△	80℃ hot water	X		○	Hard to see steps	△	Bounce	○	6
Stone powder	4	Srone powder	D	200g	¥100	○		△	Not stick to hands	○		○			7
	5	Unglazed	D	200g	¥100	○		△	Easy to handle	○		○	Feel worth	○	9
Wood powder	6	Wood powdwe	D	-	¥100	○		△		○		○			7
	7	Cypress powder	D	-	¥100	○		△		○		○	Scent of cypress	○	9
	8	Cork	D	-	¥100	○		○		○	Hard to see steps	△			7
Paper	9	Paper	D	500g	¥100	○		X	Hard to remove	△		△			4
	10	Lightweight	D	-	¥100	○		○	Hard to remove	X	-	X			4
	11	Phosphorescent	D	32g	¥100	○		○	Not stick to hands	○		○	Glows	○	10

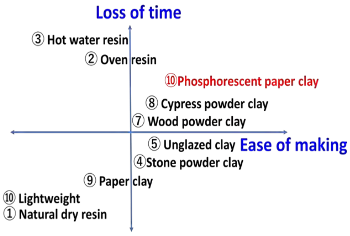


Figure 13 Ease of making and time

Outer frame type	Extrusion type	Direct case type
		

Figure 14 Study on how to make in 10 minutes

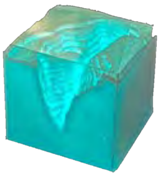


Figure 15 Suruga Bay topography model

Figure 16 Suruga Bay Ferry

Figure 17 Izu Shirakabeso

Results and Discussion

(1) KV-BIKE project

In the university/technical college division of the Ene-1 GP Suzuka, we got second place in 2017 and third place in 2019. Also, at the Ene-1 GP Motegi, 2016 winner, 2017 winner (Class I "general / university / technical college" category "3rd place overall"), 2018 runner-up, 2019 3rd place, 2022 3rd place and 7 times Shining on the podium.

In addition, since 2018, we have been supporting the junior high school team of Mishima City with the support and cooperation of the Department of Electrical and Electronic Engineering. 2018 Ene-1 GP Suzuka Junior High School Champion (Class II “High School/Junior High School” Category “3rd Overall”), 2019 Champion, 2021 Champion, 2018 Ene-1 GP Motegi Junior High School Champion and 2019 Champion, In this way, the junior high school team has won the championship five times.

Figure 18 Technical college students and junior high school students working on KV-BIKE

(2) Deep sea project

Presented at the 2019 Annual Meeting of the Zoological Society of Japan Chubu Branch. In the poster presentation, " 100 to 200m deep sea survey in Numazu, Suruga Bay using a real-time system" won the Excellence Award, and " 500 to1500m deep sea survey in Numazu, Suruga Bay using a 4K video recording system" won the competition chairperson award.

Furthermore, in the oral presentation, "Challenge to 1500m in the Suruga Bay Deep Sea by Numazu National College of Technology Students" won the Excellence Award and the Conference Chairman's Award. At the

2021 Annual Meeting of the Zoological Society of Japan, "Investigation of 1750m deep water in Suruga Bay using a compact 4K imaging system" and 2022 Annual Meeting of the Zoological Society of Japan, "Deep sea topography and marine snow accumulation using a 3D model of Suruga Bay" and "From deep sea research in Suruga Bay to production of on-board educational programs", we received the Excellence Award. At the 2022 Annual Meeting of the Zoological Society of Japan Kanto Branch, we made a presentation titled "Suruga Bay 500-2030m topography and biological survey using a compact 4K imaging system".

(3) Educational material development project

The 3D block coelacanth will continue to be exhibited at the Numazu Deep Sea Aquarium in 2023. This creates value in terms of children's interest in deep sea creatures and interest in manufacturing. In addition, improvements have been made as a product that requires increased reliability through long-term exhibition. Observation of the turn alternation of Bathynomus doederleinii has led to a presentation at the Zoological Society of Japan. The Suruga Bay Education Program was used in the Suruga Bay Classroom for elementary and junior high school students at the Suruga Bay Ferry and Izu Shirakabeso. In collaboration with the Suruga Bay Ferry (transportation) and the inn (accommodation) on the Izu Peninsula, we proposed and constructed a new tourism model combining tourism and intellectual property creation education materials, with Suruga Bay as a campus for intellectual property creation education. Taking advantage of intellectual property creation activities, we challenged the patent contest and were able to win the Patent Office Commissioner's Award for the 2020 Hatogi Project (knife sharpener) and the 2021 Ryota Suzuki (rubber band gun) for two consecutive years.

Conclusions

Through the practice of the Tongs model through real challenges such as Suzuka Circuit, Twin Ring Motegi, Suruga Bay, and Numazu Deep Sea Aquarium, the following things were clarified.

(1) KV-BIKE is effective as environmental and energy education for technical college students, and it is also an effective activity for junior high school students to develop sharp human resources by working together with technical college students and junior high school students.

(2) The water depth of the Suruga Bay deep sea survey was able to realize a 100% inclination in one year. This is equivalent to the technological development of hard disks introduced in The Innovation's Dilemma, and is effective as an innovative human resource development.

(3) The 3D block coelacanth and the Suruga Bay model using TRIZ's inventive principle and contradiction matrix are asset as Suruga Bay teaching materials such as the Suruga Bay Ferry and Izu Shirakabeso are effective in creating added value for tourism as new tourism models.

(4) We were able to show two models of creative activities, group and individual, which are conscious of utilization, such as winning the Patent Office Commissioner's Award for two years in a row in the patent contest.

Acknowledgements

In promoting intellectual property creative education, I would like to express my deep gratitude to everyone at the Cabinet Office Intellectual Property Creation Education, WIPO Japan Office, Patent Office, Japan Patent Attorneys Association, Invention Promotion Association, INPIT, Shizuoka Prefecture, Numazu City, Mishima City, Suruga bay Ferry, Numazu bay Deep Sea Aquarium, Yamaha Marina Numazu, Izu Matsuzaki Marina, LaLaport Numazu, and Artec Co., Ltd.

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A Case Study of the Engineering Ethics Education and Developing Teaching Materials

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Abstract

Preceding studies on engineering ethics education in Japan have mainly focused on the educators' perspective. The authors are currently engaged in the "Improvement of Education and Development of Effective Learning Materials through Practical Education Research of Ethics Education for Engineers".

Our study focuses on the interaction and learning process between teachers and students in an engineering ethics class, using discourse analysis and video review. In our research, we conducted a trial engineering ethics class, recorded group work, and made transcripts.

After analyzing the transcripts and video review, we found that students not only completed the assigned tasks but also constructed better arguments, dynamically adjusting, and integrating their knowledge through discussions. In addition to that, we pointed out that the discourse analysis and video review will also work for teachers to improve their classes effectively.

Furthermore, based on the results of these analyses, our research project will also work on developing new engineering ethics education materials. Last year, we tried to create learning materials with our Environmental studies class students.

In this endeavor, we have incorporated the Serious Board Game Jam (SBGJ). SBGJ is a combination of three words such as "Serious game" which means to think about social issues, "Board game" and "Game Jam" which means to create a game together.

Creating games in groups has advantages over lecture-type classes so that they can learn independently even while having fun. It also requires a sense of fun and design. It is not only "fun". The theme of the ethical problem must be appropriately set, and the conditions, definitions, and rules of the game cannot be created without understanding the structure of the problem that has been set. Furthermore, to create a good game, it is important to consider the users' point of view to devise and implement tricks so that users can enjoy the game and not get bored. In conclusion, the creation of game-type learning materials requires abstraction and communication skills. In other words, it is not only fun but also a learning process with high educational effects.

Based on the results obtained from this report and the issues it addresses, we would like to work on the creation of learning materials on engineering ethics next year.

Keywords: *engineering ethics, discourse analysis, learning process, learning materials, serious game*

Introduction

Preceding studies on engineering ethics education in Japan have mainly focused on the educator's perspective. However, teaching is a "complex activity involving diverse values and factors" (Akita & Sakamoto, 2015, p. 228) and "an interaction that students develop with others over the content of the subject matter" (Akita & Fujie, 2019, p. 3).

In this sense, educational research in engineering ethics requires not only curriculum development using pre- and post-questionnaires to students, but also observation and description of how teachers and students act and discuss during class, how teachers teach, and how students acquire knowledge.

The authors are currently engaged in the "Improvement of Education and Development of Effective Learning Materials through Practical Education Research of Ethics Education for Engineers". Our study focuses on the interaction and learning process between teachers and students in engineering ethics class, using discourse analysis and video review. In our research, we conducted a trial engineering ethics class, recorded group work, and made transcripts (Takehara, 2021) (Takehara & Fujiki, 2021).

As a result, we found that students not only completed the assigned tasks but also constructed better arguments, dynamically adjusting, and integrating their knowledge through discussions. In addition to that, we pointed out that the discourse analysis and video review will also work for teachers to improve their classes effectively (Takehara & Fujiki, 2022).

In this paper, firstly, we summarize the educational research using discourse analysis and video reflection on our research project. And secondly, we will also report on our efforts to develop learning materials that include game elements on the theme of environmental issues through a trial class in 2022.

Discourse Analysis of Student Discussion in "Engineering Ethics"

One of the characteristics of ethics education for engineers is that there are no predetermined correct answers. Therefore, it is important to learn how to reach conclusions. Video materials have been produced to present issues and perspectives without explicitly stating conclusions.

So there, in 2021-2022, we conducted a trial engineering ethics class at the National Institute of Technology (KOSEN), Nara College, recorded group work, and made transcripts. The class progressed as follows: First, students studied the "Seven-step Guide to ethical decision-making" (Davis, 1999) by watching the video learning material (Muroran IT, 2008). Next, they watched the "Solar Blind" video (Kanazawa IT, 2009). Finally, the class was divided into groups, and group work was conducted based on the "Seven-step Guide to ethical decision-making".

Figure 1 Video recording of group work (the July 2021 class data)

From the transcripts and video recordings, we analyzed and considered "the process of discussion = the learning process of ethics for engineers," "how group work works," and "how teachers interact and work with the students".

As a result, we obtained the following three findings. First, each group proceeded with discussions based on different procedures, different conclusions, processes, and durations. Given the diversity of the discussion process, teachers need to evaluate not only the results of group work but also the process to develop problem-solving skills in group work.

Second, we focused on the inherent nature of group work itself. We found that students discussed the contents of engineering ethics, and "how to work in groups" at the same time. We found that during the discussion, they often showed their understanding by nodding, agreeing, and repeating others' opinions, and such attitudes activated the discussion and also showed their implicit acceptance of others. Therefore, teachers should be aware of the process that students accept others in group work, in other words, it is important to recognize the discussing issues in a democratic and open relationship and to advise them so that they can create such an environment.

Third, we focused on the teachers' behavior and analyzed how they interact and cooperate with students. We found that teachers were involved with students while engaging in various behavioral patterns such as providing guidance, questioning/utterance, patrolling, and advising in the classroom. However, not all of these actions were successful (of course, appropriate guidance may be given). This indicates that it is effective for teachers to review the video to get their class improved. Teachers can improve their lessons appropriately by analyzing the factors of "success or failure of behavior in the lesson" while recognizing "teacher involvement" and "student reaction".

As described above, the analysis of the learning process through discourse analysis in group and video review revealed several important perspectives and issues. These were shown to have the potential to improve classroom teaching.

Development of learning materials

Based on the results of analyses of the learning process in Engineering Ethics, our research project will work on the development of new materials.

In preparation for full-scale implementation, last year, we were challenged to create game-type learning materials over the theme of environmental problems in a general education elective Human Environmental studies class for fifth-year students at National Institute of Technology(KOSEN), Nara College.

While conducting the class, we have incorporated the Serious Board Game Jam (SBGJ) taking into account the characteristics of students in KOSEN who prefer experiments, practical training, and hands-on work. The name "Serious Board Game Jam (SBGJ) " is a combination of three words such as "Serious game" which means to think about social issues, "Board game" and "Game Jam" which means to create a game together (Figure 2). The term was named by Kazuhiko Ota, an associate professor at Nanzan University, Japan (SBGJ2022, 2022).

Figure 2 Illusts of SBGJ (SBGJ2022, 2022)

In the class, students learned basic knowledge such as the current state of environmental problems, legal system, environmental conservation technologies for air, water, and soil, environmental indicators and monitoring, environmental ethics, and living environment in a lecture format.

After that, students were divided into groups and worked to create experiential learning materials that would enable participants to think seriously about the environment while having fun and playing games based on what they had learned in class.

In the group work, the students were first asked to experience some serious board games. Then, the students worked on game ideas and actual production activities. Finally, students gave final presentations about their games to real-life policymakers, who worked for the Environmental Policy Division of Nara Prefecture.

Students created a very wide variety of games: a speed game to sort trash, a card game to balance industrial development and environmental sustainability, a game to experience the benefits and challenges of building and operating a power plant, a card game to guess the habitat of endangered species, a poker game to learn how to dispose of trash, a game to experience the pleasantness of environmental conservation and the discomfort of pollution, a card game to learn about environmental issues, and a game of cards to learn about environmental problems, a karuta game to learn environmental issues, and a board game in which villagers cooperate to overcome natural disasters. Some of the groups used 3D printers and laser cutters to create prototypes (Figure 3). Another group created a card game linked to the Web by programming by themselves (Figure 4).

Figure 3 Prototype for a game made with a 3D printer

Figure 4 Creating a card game linked to the web

Creating games in groups has advantages over lecture-type classes so that they can learn independently even while having fun. It also requires a sense of fun and design. It is not only "fun". The theme of the ethical problem must be appropriately set, and the conditions, definitions, and rules of the game cannot be created without an understanding of the structure of the problem that has been set. Furthermore, to create a good game, it is important to consider the users' point of view to devise and implement tricks so that users can enjoy the game and not get bored.

In conclusion, the creation of game-type learning materials requires abstraction and communication skills. In other words, it is not only fun but also a learning process with high educational effects.

Conclusions

In this paper, we summarized the educational research using discourse analysis and video reflection on our research project and described our efforts to develop learning materials that include a game element on the theme of environmental issues through a trial class in 2022.

The analysis of discourse analysis and video reflection revealed the following.

First, the generation, confrontation, transformation, and integration of arguments that occur in group work and discussion, in other words, the process of debate, are important. In addition, there is an inherent nature of group work, and classes should be conducted on this basis. Finally, the effectiveness of teachers' video reflections in improving their classes was pointed out.

And the creation of game-type learning materials requires abstraction and communication skills. In other words, it is not only fun but also a learning process with high educational effects.

Based on the results obtained from this paper and the issues it addresses, we would like to work on the creation of learning materials on engineering ethics next year.

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A CASE STUDY OF THE SIGHTSEEING TOUR BOAT ACCIDENT OFF THE SHIRETOKO PENINSULA AND PEDAGOGIC IMPORTANCE OF CASE STUDIES IN ENGINEERING ETHICS EDUCATION

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Abstract

We explore a case study on an accident and show how it can be a pedagogical source of engineering ethics education for technical college students. We deal with a sight-seeing tour boat accident off the Shiretoko Peninsula which occurred on April 23, 2022. A tourist boat *Kazu I* sank with twenty-six people on board in bad weather. The Japan Transport Safety Board (JTSB) issued a progress report of this accident on December 15, 2022. This report identifies six factors of the accident but does not discuss any ethical problems from the point of view of engineering ethics. Among the factors, we examine the hull structure, a judgment by the captain, and the non-compliant attitude of an operating company as potential subjects in engineering ethics classes. According to the report, for instance, the boat was running with its hatch not fixed and closed without good reason, and the seawater flowing into it from the hatch is supposed to be one of the principal causes of the sinking. Can engineers predict the possibility of a shipwreck and advise the company to repair the hatch? Why did not the captain exercise good judgment on the departure from the port? These questions can be the topics of discussion in engineering ethics classes. After looking into the causes of the accident spelled out in the report JTSB issued, we argue the pedagogical importance of new case studies in engineering ethics education. While classical cases we can see in textbooks of engineering ethics are easy to treat, new ones are difficult to argue because of a lack of previous research. There is, however, room for free discussion in a recent case, and it can attract students more because they may know it well in the latest news report. These advantages enable students to think about the case as a person concerned.

Keywords: *engineering ethics education, sightseeing tour boat accident, bounded rationality, cost-benefit analysis, the importance of case study*

Introduction

This study aims to analyze a recent incident case that had a social impact in Japan and to consider the perspectives of dealing with such case studies in courses of engineering ethics education. Engineering ethics education in KOSEN is developing, and its methods and contents should be refined further (Kobayashi, 2007; Souma, 2018; Shimura, 2022). In general, we derive various analytic points of view from past research on social accidents. It goes without saying that there is little research on the latest incidents. Case studies enable us to recognize ethical problems in engineering, cultivate and exercise our moral imagination, and prevent terrible accidents (Harris et al., 2000). Accumulating good case studies is thus an essential issue for engineering ethics education. We should search and deal with the latest cases to contribute to engineering ethics education for technical college students.

We deal with a sight-seeing tour boat accident off the Shiretoko Peninsula caused on April 23, 2022. Media reported this incident widely and repeatedly, and people got angry about the negligence of the operating company. We discuss this accident as follows. We outline the accident based on a progress report issued by Japan Transport Safety Board (JTSB) in December 2022. We rely on it only to summarize the accident because it just presumes the causes of the accident and suggests how we should improve the management of leisure boats but does not identify the problems for engineers. The Japan Society of Mechanical Engineers reported that this accident is a case of engineering ethics (The Japan Society of Mechanical Engineers, 2023). However, these two documents do not clarify how this case concerns engineering ethics. We try to make clear the ethical problems and discuss them with the help of philosophical studies on engineering ethics.

1. Outline of the accident

1-1. Outbreak

A tourist boat *Kazu I* sank with twenty-six people on board in bad weather on April 23, 2022. The boat company Shiretoko Pleasure Cruise operated it. The Shiretoko Peninsula, designated a natural World Heritage Site in 2005, is a popular destination for observing drift ice and rare animals. Twenty bodies were recovered from the sea of the Shiretoko area, with six missing. No survivors were found. According to the bereaved, all found passengers died of suffocation.

The ship, crewed by a 54-year-old captain and a 27-year-old deckhand, started cruising at 10:00 from Utoro port to Shiretoko Cape. It was a 3 hours cruising tour off the coast of Shiretoko Peninsula. The sea looked calm at Utoro port in the morning, but it would be stormy off Shireroko in the afternoon. The Japan Meteorological Agency issued a gale advisory at 3:09 on the day for Shari Town and a high-surf advisory at 9:42. An employee of another boat company advised the captain not to set out for sailing before the departure of *KAZU I*.

The cruising seemed to be plain sailing in the morning. An employee working for another company in the same industry, who heard from the captain of *KAZU Ⅲ* that it had gotten windy in the sea, called the captain of *KAZU I* at 11:47, 12:05, and 12:47 but had no response. He used a radiotelephone of his company to talk with the captain, who responded at 13:07 that the ship was at the point of Kashuni-no-Taki Falls and would return to the port behind the presumed time. He continued intercepting the radio, in which the captain signaled that the boat was flooding with water and sinking. He reported it to the Japan Coast Guard (JCG) at 13:13. JCG received an emergency call from one of the passengers at 13:18. At 13:26 or later, the ship went missing with 26 people on board.

1-2. Search for survivors

At 16:15, JCG dispatched five patrol boats and two aircraft to search for survivors, but they could not find the missing people and the pleasure boat during the day. At 5:01 or later the next day, several passengers were found and rescued near Cape Shiretoko, whose death was confirmed. Japan Maritime Self-Defence Force searched the ship by using underwater cameras and found it at a depth of 120 meters of the sea near Kashuni-no-Taki Falls on April 29. It looked into the boat with a remotely operated vehicle on May 8 or later. On May 19, 20, 21, and 23, a diver searched for the missing person in the cabin. The boat was salvaged and towed toward Utoro port but dropped into the sea on May 24. It was salvaged again on May 26 and unloaded at Abashiri port on June 1st.

2. Analysis of the accident

2-1. Six factors of the accident

The progress report JTSB issued in December 2022 identified six factors of the accident as below.

1) Hull structure
2) Judgment on the departure
3) Compliance with the codes of safety and management
4) Effectiveness of inspection
5) Lifesaving equipment and telecommunication device
6) Framework of search and rescue

Among them, engineering ethics can concern the hull structure, the judgment on departure, and compliance. We examine these three causes one by one.

2-2. The problem of a hatch and water tightness

As for the structure, JTSB points out the wrong position of a hatch and unsatisfactory water tightness. The captain could not supposedly see the hatch from the pilothouse because the location of the hatch was at a blind angle. It was fatal in this incident because one of the principal causes was the water intruding from the hatch into the compartment and then into the engine room, which caused the shutdown of fuel injection and prevented the ship from advancing into the sea. JTSB presumes that the boat would have avoided a loss of control if it had kept the water tightness of its bow compartment.

2-3. Captain's decision making

The captain set out for sailing even though he was advised not to sail in supposedly terrible weather. We cannot reveal why the captain decided to set out because it is impossible to hear from him. We can only say that this accident would not have occurred if the captain had held back the decision for departure.

2-4. Violations against safety management codes

Did the operating company meet the compliance requirements? There is no recording of consultation between the captain and the company leader, even though the company's safety management codes require a discussion between them when it is difficult for the captain to cancel the cruise due to the weather. In addition, they also demand that the president works in the office while the boats are cruising, but the president was not there when *KAZU I* was on a cruise on April 23. Thus, we observe certain violations against the codes, which became a dead letter in their daily operations. Furthermore, there does not seem to have been a climate of observing them in the company.

Hokkaido District Transport Bureau performed unannounced inspections several times before the accident, especially on April 21, 2022, two days before the accident. The ballast positions in *KAZU I* were different from those that the ship examination certificate designates. In addition, the hatch had not been closed when the ship was running. Inspectors could not find the problems of the ballast's wrong positions and the broken hatch.

3. Discussion from viewpoints of engineering ethics

3-1. Trade-off condition

The report issued by JTSB clarifies six factors behind the accident and suggests how we should avoid the same kind of accident. It does not discuss any ethical problems from the point of view of engineering ethics. What sort of engineering problem can we find in this accident?

Engineers are expected to find not the perfect but the best solution under the trade-off conditions (Saito, 1998). Under bounded rationality, engineers cannot elucidate all causality of this world. Despite this, they must design and produce artificial products with maximal care for the public and their client (Saito, 2001). *KAZU I* is a ship originally designed for sailing in a calm sea, which probably lowered the priority of the hatch because it is inconceivable that seawater gets into the boat from the hatch and high waves destroy the hatch. When the owner changed, the sailing area also changed. In a stormy sea such as the Okhotsk Sea, it should have been necessary to bring the hatch into sight from the wheelhouse and vital to keep the water tightness of the bow compartment. It is doubtful, however, as far as we can suppose, with our bounded rationality, that the hatch positioned at a dead angle from the pilothouse and unsatisfactory water tightness would be a crucial defect for the ship in a stormy sea. This question may enable students to recognize the nature of bounded rationality and consider how they should act in similar situation.

3-2. Cost-benefit analysis

No one can testify why the captain set out for sailing that morning. We can point out at best three reasons he decided on his departure. The weather was not so terrible when he judged the cruise would be safe. He might think the company could not earn fare receipts if it cancels the cruise. The captain might consider the wishes of passengers boarding the pleasure boat at any cost. He must have estimated various conditions at the same time. Could engineers insist on the safety of passengers and show their reasons to a responsible person for operation when they find a conflict between the company's profit and the passengers' security? Generally, cost-benefit analysis is helpful for seeking the reason for a conduct amid the conditions. It is true that, as the Ford Pinto case indicates (Saito, 2001), a company has a positive reason for raising the priority of pursuing its profit to some extent, even though it damages the safety of users. In the boat case, the captain probably prioritized the wishes of passengers, but if he had weighted heavily on the lives of passengers in the analysis, his decision-making might have changed. Thus, this case will be an occasion to know and discuss the cost-benefit analysis much biased on the safety.

3-3. Compliance

Compliance, an attitude to obey the codes of ethics of the organization, is essential for every member of society. But they often make amoral actions as if they forgot the importance of compliance. Japanese industries imported the code of ethics from the U.S. several times after Meiji Period (Natsume, 2021). Engineers improved them each time they established a new organization for engineers. They needed them to make sure of their judgment and behavior in ordinary operations. The effectiveness of the codes is, however, doubtful because it seems to be a mere slogan, and would not play a sufficient role of guideline in an actual situation (Iwasaki, 2000). The report issued by JTSB suggests that the employees of the boat company had not followed their company codes of safety management and that it was one of the causes of the accident. We still have to question students on how we enhance the consciousness of compliance in daily operations.

4. Teaching scheme

4-1. Purpose

This missing boat case can be a moral lesson about the scent of danger, the biased cost-benefit analysis, and a judgment in favor of safety and security. In a class where we treat the case, we aim to cultivate students' ability to catch the scent, utilize the analysis, and make good decisions.

4-2. Lesson

4-2-1. Introduction

We start with the introduction of the case. TV documentaries, articles on the internet, and the JTBS reports are available. It will be more efficient for students to overview them ahead of the class.

4-2-2. Analysis

Students conceive the background and causes of the accident based on the materials mentioned above. Students think about them individually and talk about them in a group. So that students discuss something in a class, they must find out the questions to discuss. The teacher can help them find the questions as we identify three crucial ones: how we suppose, with our bounded rationality, that the hatch positioned at a dead angle from the pilothouse and unsatisfactory water tightness would be a crucial defect for the ship in a stormy sea?; could engineers insist on the safety of passengers and show their reasons to a responsible person for operation when they find a conflict between the company's profit and the passengers' security?; how we enhance the consciousness of compliance in daily operations?

4-2-3. Discussion

After identifying the questions students should treat, they discuss them to make clear what they should do in the same situation. Students give a presentation about their discussion and debate with the audience. At the end of the class, students write down what they learned on the communication paper.

5. Pedagogic importance of the latest cases

We generally think of engineering ethics education as lessons for students who will become engineers or researchers to make good decisions when they need to make ethical judgments and behavior (The Institute of Electrical Engineers of Japan, 2014). It is necessary not only to enrich their knowledge but to let them think as a person concerned. A case study is an adequate pedagogical method for this objective.

What kind of example is appropriate for the case study in engineering ethics education? We can access a lot of good cases many engineers and researchers have accumulated. Engineers are interested in specific, concrete, or practical problems (Harris et al., 2000). Focusing on a case with these qualities seems to be a better approach to attracting students' attention. We always need to select attractive and proper ones based on the interest of the students we take charge of.

We also think about the advantages of treating the latest cases. In classical textbooks, such as Ethics for Science-Engineers: Concepts and Cases (Harris et al., 2000) published in the U.S., there are ample case studies helpful for our understanding and consideration of engineering ethics. However, we also recognize that an ethical analysis in a case study leaves room for some uncertainty (Harris et al. 2000). It is risky to believe the answer described and proposed by the analyzer. We are, nevertheless, apt to accept a solution in the textbook without question. At this point, classical studies are accessible but not enough to stimulate students to analyze the case and find a solution for themselves. The latest ones are, on the contrary, immune to the fixed viewpoint and solution powered by the researcher's authority. Moreover, in new cases, students are likely to acquire information timely, get interested in the current topics, and think critically about them because they have to think by themselves.

Conclusions

We treated a boat accident in this paper. JTSB says it needs more time to finish the final report, in which we would find a detailed and thorough analysis. We just mentioned three questions on the viewpoints of engineering ethics. The questions are open to students' free and creative discussion because there are no decisive arguments about them.

We hypothesize that treating the latest cases in engineering ethics class is advantageous enough to give students materials to think and argue with ease. It is an intuitive opinion and has no evidence that confirms the hypothesis. Having materials of the latest case studies on social accidents, using these materials in lectures of engineering ethics classes, and testing this hypothesis will be the next problem for this study.

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KEY RESEARCH THEMES IN ETHICS AND ARTIFICIAL INTELLIGENCE IN EDUCATIONAL ASSESSMENTS

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Abstract

This systematic literature mapping study aim to provide practical insights on the ethics of artificial intelligence (AI) in assessment. It is important to study the divide between what may be ethically permissible and not permissible, especially in fundamental societal institutions like education, when teaching practitioners or researchers apply AI in academic processes such as assessments. This study applied a systematic literature mapping methodology to scour extant research, so as to holistically structure the landscape into explicit topical research clusters. Through topic modelling and network analyses, research mapped key ethical principles to research archetypical domains, and reviewed the influence of these ethical principles in each thematic domain. Results of this study identified five key research archetypical themes, with presence across the system layers of cognitive, information and physical domains of an AI-based assessment pipeline, namely: (i) AI system design and check for assessment purposes; (ii) AI-based assessment construction and rollout; (iii) data stewardship and surveillance; (iv) administration of assessments using AI systems; and (v) AI-facilitated assessment grading and evaluation. Ten AI ethics principles, namely, (i) fairness, (ii) privacy, (iii) explainability, (iv) accountability, (v) accuracy, (vi) inclusivity, (vii) trust, (viii) human centricity, (ix) auditability and (x) cheating, epitomize the key ethics considerations across each of the five research themes; each manifesting varying levels of importance. The findings of this research can provide researchers and practitioners the insights into the application methods of AI in assessments and their intertwined ethical challenges, and in particular, the generalizable key research themes structured across the assessment pipeline, for follow up studies.

Keywords: *artificial intelligence in education (AIED), assessment, ethics, systematic literature mapping*

Introduction

Artificial intelligence in education (AIED) is the machine mimicry of human-like consciousness and behavior to achieve educational goals, through the use of technology that allows digital systems to perform tasks commonly associated with intelligent beings.

Of the three pillars of education, assessment exists as an important component, alongside pedagogy and curriculum (Hill and Barber, 2014). Within the AIED domain, Chaudhry and Kazim (2022) scoured the landscape and concluded that assessment is one of the four key sub-domains in AIED, alongside learning personalization, automated learning systems, and intelligent learning environments. In an educational context, assessment refers to *'any appraisal (or judgment or evaluation) ... of work or performance'* (Sadler, 1989). The infusion of artificial intelligence (AI) in assessments has grown significantly in recent years. Research on assessments related to digital education in the higher education landscape showed that AI and adaptive learning technologies have tripled between 2011 to 2021 and is likely to surpass immersive learning technologies as a prime research area in the near future (Lim, Gottipati and Cheong, 2022). Among stakeholders, there is a consensus positive view that "*AI would provide a fairer, richer assessment system that would evaluate students across a longer period of time and from an evidence-based, value-added perspective*" (Luckin, 2017).

Infusion of AI in assessments also brings along its own set of concerns. AI implementation comes with technical and operational issues relating to system implementation. Arguably, these challenges have relatively lesser grey areas to contend with, than the complication of navigating the parameters and boundaries of ethics. Evaluators, as practitioners of assessments, will need to acknowledge, respect, and uphold ethical principles that may plague the implementation of an AI-based assessment.

The research objective of this study is to examine the landscape of AI-related ethical issues for educational assessments, through the lens of a systematic literature mapping approach. A systematic literature mapping study is a study concerned with the mapping and structuring of a topical research area, the identification of gaps in knowledge, and the examination of possible research topics (Petersen, Vakkalanka and Kuzniarz, 2015). The research novelty and value of this work lies in the notable lack of research providing a holistic inspection and review of the aforementioned landscape.

This study investigates the following research questions:

- *RQ1: What are the main AI use cases and ethical issues relating to assessments?* This question looks at AI applications and ethical principles in different assessment areas, and how dominantly each area is featured.
- *RQ2: What are the key themes of the systematic literature map?* This question looks to identify key themes of the systematic literature map, and draw up a framework to visualize and generalize the key themes for researchers and practitioners.

The significance of this research is, through a systematic meta-analysis of existing literature in the field, (i) understand and consolidate knowledge regarding what was previously explored relating to AI-based assessment methods and their interconnected ethical issues, (ii) provide an integrated inquiry into the association of the ethical problems faced, and (iii) identify potential future research topics in the field.

Results of this study identified five key research archetypical themes, with presence across the system layers of cognitive, information and physical domains of an AI-based assessment pipeline, namely: (i) AI system design and check for assessment purposes; (ii) AI-based assessment construction and rollout; (iii) data stewardship and surveillance; (iv) administration of assessments using AI systems; and (v) AI-facilitated assessment grading and evaluation. Ten AI ethics principles epitomize the key ethics considerations across each of the five research themes; each manifesting varying levels of importance.

The remainder of the paper is organized as follows: (i) the Methodology section discusses the systematic literature mapping approaches undertaken, explains the machine learning methods utilized; (ii) the Findings section presents the tables and graphic visualizations from topic modelling, and network analyses, and provides in-depth analyses of the data.; (iii) the Conclusion section summarizes the key findings, impact of paper, and closes with proposed future work that can be studied by practitioners and researchers.

Methodology

In this study, we apply the systematic literature mapping approach. The study was conducted using the research methodology in Kabudi, Pappas and Olsen (2021). We apply the methodology undertaken as follows, namely: (i) search and selection, (ii) data extraction, and (iii) classification and analysis.

PRISMA approach, or the Preferred Reporting Items for Systematic Reviews and Meta-Analyses approach, was employed as a guideline to conduct the search and selection phase (Moher et al., 2009). In accordance with the recommended methodology as part of the PRISMA-P checklist, details including the eligibility criteria, sources of information, search protocol, research records, data items and synthesis of data are described in the following sub-sections.

Vivo11, EndNote X9 and *Excel* spreadsheets were used for information organization. Further information extraction, data visualization, and machine learning tools and techniques are described in the following sub-sections.

Search and Selection

As AIED researchers stem from a variety of fields publishing across a wide range of publications, literature search was conducted using Scopus, an interdisciplinary rigorously curated database covering the widest range of disciplines (240 disciplines) relative to similar citation databases, with contents including over 87 million publication items, 1.8 billion cited references, 17 million author profiles, 94,000 affiliation sources and 7,000 publishers. On average, each paper indexed on Scopus has 10% to 15% more citations than similar databases (Elsevier, 2022), which implies a more extensive systematic literature mapping analysis. Summary of PRISMA approach is shown in Fig. 1.

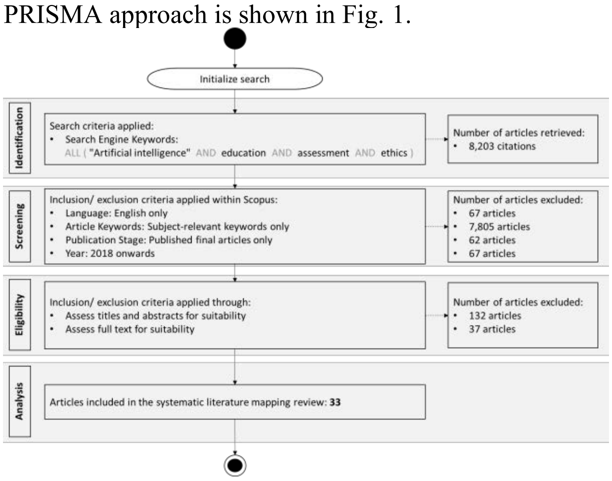


Figure 1: PRISMA - The systematic mapping process

The first stage of PRISMA, or the *identification stage,* identifies the possible papers to be considered using the Scopus search engine. The search entry was as follows: *ALL ("Artificial intelligence" AND education AND assessment AND ethics).* This stage identified a corpus of 8,203 papers.

The second stage of PRISMA, or the *screening stage,* looks at excluding inappropriate and unrelated papers. This stage reduced the corpus count to 202. Search applied the following inclusion criteria:

- *Language:* Only articles written in English language were included. This step omitted 67 articles.
- *Keywording:* Only articles with subject-relevant keywords coded by Scopus for indexing purposes (also known as *Indexed Keywords* by Scopus) were included. This step omitted 7,805 articles.
- *Publication Stage:* Only peer-reviewed final articles published in scientific venues (e.g., books, journals and conferences) were included, for rigority of selection. This step omitted 62 articles.
- *Year of Publication:* Only articles published in 2018 and beyond were included, to ensure recency of literature. Rigorous peer-reviewed articles would

have reviewed key prior related literature within their respective papers. This step omitted 67 articles.

The third stage of PRISMA, or the *eligibility stage,* requires scanning title and abstracts, and full papers to identify relevant eligible articles. This stage yielded a final corpus count of 33 articles. Search applied the following inclusion criteria:

- *Assess Titles and Abstracts for Suitability:* Only relevant titles and abstracts were included. There should be explicit and direct references to the subject matter. This step omitted 132 articles.
- *Assess Full Papers for Suitability*: Only relevant full papers were included. An additional inclusion criterion here was that all articles should have their full text accessible for analysis. This step omitted 37 articles.

Data Extraction

As a citation engine, data in Scopus is highly structured and robustly tagged, delivering metadata for analytical purposes, including (i) author(s), (ii) document title, (iii) affiliation(s), (iv) year, (v) publication, (vi) volume, issue and page source, (vii) citation, (viii) document type, (ix) keywords, and (x) digital object identifier (DOI), among others.

The final pool of 33 primary studies were analyzed to answer the research questions of this study. Information that was extracted from Scopus included: (i) citation information, such as author(s), title, year, publication, and citation count etc., (ii) bibliographical information, such as affiliation(s), and publisher etc., (iii) abstract, (iv) keywords, and (v) references.

Classification and Analysis

Using the data extracted from Scopus, the study utilized *Tableau Desktop Professional version 2021.1.20* to perform exploratory data analyses to address RQ1. Tableau platform allows powerful conversion of complex computations into appealing data visualizations.

With the Scopus extracted data, research utilized a corpus analysis platform *CorTexT* (Breucker et al., 2016) to perform text parsing, and a first pass of topic modelling and network mapping, so as to identify major thematic representations of corpuses comprising of *Author Keywords* and *Indexed Keywords*. This allowed us to perform machine learning for pattern recognition, utilizing unsupervised text mining techniques on these keywords to identify useful patterns.

Using the Python Library *pyLDAvis* (Sievert and Shirley, 2014), topic modelling generated a topic representation of the keyword corpus' textual fields using the *Latent Dirichlet Allocation* method, which allowed a visualization of the most relevant words fitting to the topic. Here, each topic was defined as a keyword probability distribution, and each document was defined as a topic probability distribution. Given the total number of topics defined, the topic model was inferred by probabilistically assigning topics to documents, and positioned in 2D according to a multi-dimensional scaling algorithm for visualization purposes.

While topic modelling provided a sense of the latent themes from the underlying keywords, research further performed network analyses to visualize thematic keyword representations in a clustering format, where each keyword was grouped with distinct members, and linked via proximity measures. The Louvain hierarchical community detection algorithm was used. This algorithm is based on modularity optimization, where the optimal linkage densities are measured, taking into account within-cluster and between-cluster linkages. Louvain algorithm is efficient on large networks (Aynaud, 2020).

The first pass of topic modelling and network analyses above allowed the identification of distinct sub-themes of AI application areas and ethical issues. With the key sub-themes of AI application areas and ethical issues identified as a priori, open and axial coding were conducted for each article to classify the following: (i) application areas where AI is used in assessments (e.g., assessment curation and personalized feedback etc.), and the (ii) type of ethical issues relevant to AI-based assessments as cited in paper (e.g., fairness and explainability etc.). This would allow us to address RQ1.

Using the coded sub-themes of AI application areas and ethical issues, research undertook the second pass of topic modelling and network analyses. The topic modelling and network analyses outputs would be used to guide the identification of the major research themes to address RQ2.

Findings

RQ1: Main AI use cases and ethical issues

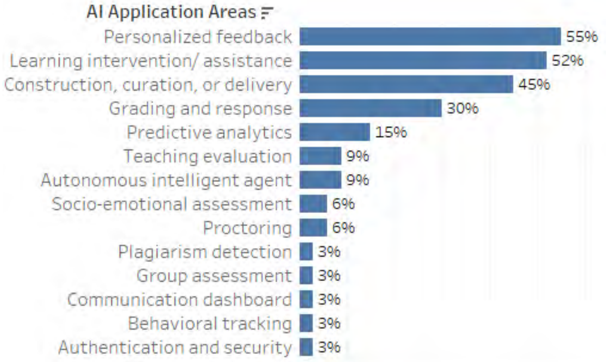


Figure 2: AI application areas and citation proportion

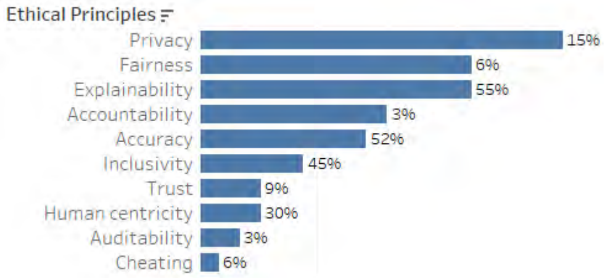


Figure 3: Ethical principles and citation proportion

To address RQ 1, topic modelling was performed, where the optimal number of topics were generated using a model with the highest topic coherence. Further, we performed network analyses to identify topic clusters. These allowed us to recognize patterns in an unsupervised machine learning approach.

From this first pass of topic modelling, ten latent topics were identified. This aligned well with network analyses, where we observed a more granular fourteen latent topic clusters. The higher granularity of the outputs allowed us to identify distinct sub-themes of AI application areas and ethical issues. Through the review of the first pass of topic modelling, network analyses outputs, and full paper reviews, the study extensively identified fourteen sub-themes of AI application areas and ten sub-themes of ethical issues. We populate them in Figures 2 and 3, respectively.

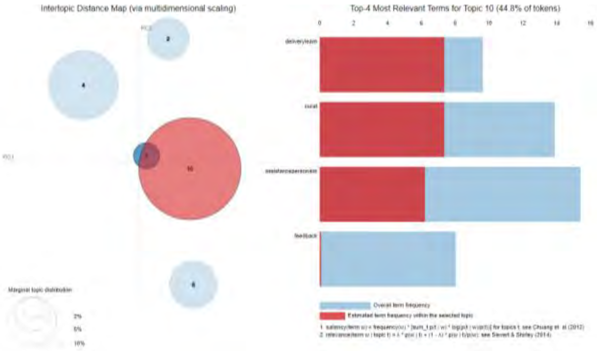


Figure 4: Topic modelling of corpuses involving AI application areas and related ethical principles

Figure 5: Network analyses of corpuses involving AI application areas and related ethical principles

Table 1: Latent topics and top keywords

Topic No.	Latent Topic	% Tokens	Top Keywords
2	System design and check	*7.5%*	System; Design; Review
9	Data stewardship and surveillance	*2.9%*	Privacy; Sensitive; Data
10	Assessment construction and rollout	*44.8%*	Deliver; Curate; Personalize
5	Assessment administration	*9.6%*	Proctor; Plagiarism; Cheat
4	Grading and evaluation	*20.7%*	Evaluation; Feedback; Response

Next, we utilize the keyword corpuses of fourteen sub-themes of AI application areas and ten sub-themes of ethical issues as an input, to perform the second pass of topic modelling, and network analyses.

Research identified five topical archetypes via topic modelling. For instance, in Fig. 4, we observed the dominant latent topic number 10 linked to AI-based assessment construction and rollout aspects. This aligned well with the network analyses visualization in Fig. 5. In the network analysis diagram, we observed a clear clustering of five topics, with *Assessment Construction and Rollout* similarly dominant in the cluster diagram. The top keywords and latent topics of topic modelling are shown in Table 1.

RQ2: Main AI use cases and ethical issues

Ashok et al. (2022) describes three fundamental domains to conceptually represent the interweaving ethical elements and interrelationships inherent in the design and application of AI in digital technologies. This triadic framework is a modular architecture of an assemblage of technological components that consist:

- *Physical domain (or the referent or object in semiotics):* This includes the device and network layer. Some relevant applications are author systems, intelligent tutoring shells, AI-integrated learning environments, and educational robotics.
- *Cognitive domain (or the symbol or science in semiotics):* This comprises the content layer where data is stored, created, mapped, manipulated, utilized, and shared. Some relevant examples are multimodal structured contents of text, and unstructured contents of images and videos of assessment submissions.
- *Information domain (or the reference or interpretant in semiotics):* This comprises the service layer which encompasses the functionality of the application and its interaction with users, underpinned by AI algorithms. Some relevant examples are use of knowledge representation for instructions, human factor and interface design, and AI-integrated visualization and graphics for feedbacks.

We extend the triadic ontological framework as described by Ashok et al., (2022) to model and visualize the systematic literature map of this paper (Fig. 5). The significance of PCI would enhance understanding of the description of the 5 archetypes below. The five distinct archetypes identified by topic modelling and network analyses in Fig. 4 and Fig. 5 are mapped to the triadic ontological framework in Fig. 6, as follows:

- *AI system design and check for assessment purposes*
  This archetype extends across the physical, cognitive and information domains, and is involved with the design, implementation and maintenance of the AI system for system interactivity, robustness and security. From a predictive analytics point of view, the model constructed should be appropriate – upholding accuracy, inclusivity, accountability, privacy, trust and human centricity.

Here, the overriding ethics considerations are explainability and auditability. The AI system should be created with clear, easy-to-understand and transparent protocols, so that relevant stakeholders and independent third-party auditors can review the processes, perform interventions, mitigate issues, and enable redress in an event of negative outcomes that may arise. In addition, fairness is concerned about the treatment of algorithmic bias to ensure diversity, equity, non-prejudice and non-favouritism towards learners' sensitive attributes, so that needs of minority groups are not disadvantaged or underrepresented.

- *Data stewardship and surveillance*

This archetype extends across the cognitive and information domains, and is involved with the governance and implementation of appropriate data stewardship, and surveillance practices (if any).

Here, the overriding ethics consideration is privacy. One instance is behavioural surveillance, which may be a violation to human rights to privacy especially when data is used beyond academic purposes, for control and surveillance to modify human behaviour. In addition, trust is also an important facet concerned about the preservation of privacy when sensitive data are disclosed.

- *AI-based assessment construction and rollout*

This archetype is predominantly situated in the information domain, and is involved with the construction, curation or delivery of assessment, the communication of evaluation and feedback with stakeholders via AI-integrated communication dashboards, and the carrying out of interventions and assistances to improve assessment and evaluation performance. Assessment and evaluation can be in the form of formative (or summative) individual (or group) cognitive (or socio-emotional) assessment. It can also be a form of teaching evaluation.

Here, the overriding ethics considerations are inclusivity and fairness, so that appropriate and equitable assessments and evaluations are rolled out, embracing diversity, empathy and sensitivity towards the evaluated stakeholders. Furthermore, accountability is an important ethics consideration, as there should exist a responsible discharge of AI ethical principles and compliance with relevant rules and guidelines, when designing and delivering AI-driven assessments. In addition, there should exist trust and confidence on AI systems to achieve assessment and evaluation objectives.

- *Administration of assessments using AI systems*

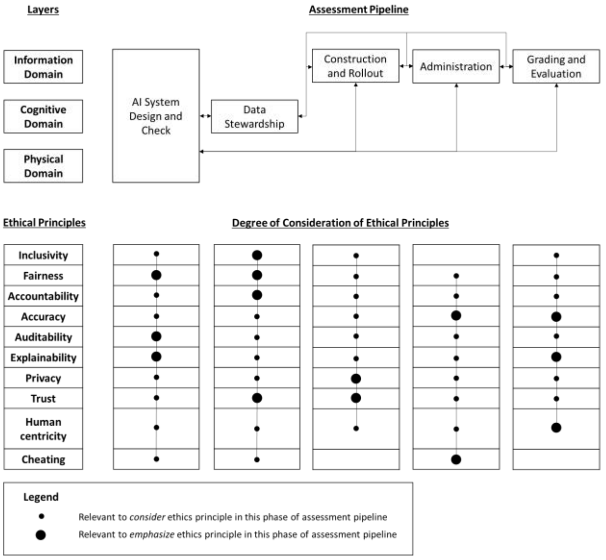
This archetype is predominantly situated in the information domain, and is involved with the administration of assessment and evaluation, which may comprise authentication and security measures, proctoring and/or plagiarism detection.

Here, the overriding ethics considerations are the overcoming of cheating violations, and the application of accuracy to correctly identify assessment candidates and cheating cases.

- *AI-facilitated assessment grading and evaluation*

This archetype is predominantly in the information domain, and is involved primarily with the interpretation of textual and/or audio-visual responses collected by AI systems, the evaluation of performance, and the provision of feedbacks. These may be performed by autonomous intelligent agents. From an educator's point of view, this phase may involve the evaluation of teaching effectiveness.

Here, the overriding ethics considerations are explainability, so evaluators can understand and adjudge if the grading and/or ranking is accurate and reliable. In addition, there is an element of human centricity. This largely relates to the agency and autonomy of human users, in the presence of AI-generated decisions, and the capacity to intervene for correction and redress.



Ethical Principles	Degree of Consideration of Ethical Principles				
Inclusivity	•	●	•		•
Fairness	●	●	•	•	•
Accountability	•	●	•	•	•
Accuracy	•	•	•	●	●
Auditability	●	•	•	•	•
Explainability	●	•	•	•	●
Privacy	•	•	●	•	•
Trust	•	●	●	•	•
Human centricity	•	•	•	•	●
Cheating	•	•		●	

Legend
• Relevant to *consider* ethics principle in this phase of assessment pipeline
● Relevant to *emphasize* ethics principle in this phase of assessment pipeline

Figure 6: Visualization of the systematic literature map of key research themes

There is an emphasis that the framework does not draw clear delineations when categorizing AI assessment use cases across triadic domains. For instance, the *Grading and Evaluation* research theme is predominantly arising from the cognitive domain. However, coding and rolling out a moral reasoning AI system for AI-generated decisions, evaluations, responses and feedbacks, a sub-item of this research theme, may straddle across all cognitive, information and physical domains. This said, the framework provides a guide to generalize observed phenomena.

Conclusion

As AI becomes more pervasive, it's important to establish ethical safeguards, particularly when there exists the possibility of anthropomorphic influence on AI. Society as a whole, and education institution in particular, should scrutinize the application of AI to mitigate potential violations of ethics, even as we push ahead to reap the benefits of AI.

In this study, we looked at how the design and use of AI in education, and in particular, assessments, can conform as closely as possible to basic ethical principles. We systematically investigated the key assessment components and ethical principles highlighted in existing literature, mapped them across the end-to-end assessment pipeline while accounting for different assessment types, and constructed a systematic literature mapping framework highlighting key archetypical research themes. The proposed systematic literature mapping framework allows researchers and practitioners to deep dive into key thematic research.

Research identified five key archetypical research themes, namely (i) AI system design and check for assessment purposes, (ii) data stewardship and surveillance, (iii) AI-based assessment construction and rollout, (iv) administration of assessments using AI systems, and (v) AI-facilitated assessment grading and evaluation. Ten literature-derived ethical principles, namely, accuracy, privacy, human centricity, fairness, inclusivity, trust, explainability, cheating, accountability and auditability, were mapped to these research themes.

Future work can extend the use of literature databank beyond Scopus, to include e.g., *Web of Science, IEEE Xplore* or *EBSCO Host*, in the systematic literature mapping exercise. While this study is based upon the subject of assessments, the ethical elements of the discourse has relevance beyond assessments, and can be applied to other areas of AIED. Other future works can contribute to the examination on the underpinning theories relating the ontological, semantics, and the epistemological deliberations and practical applications of ethics in this subject matter, across the spheres of philosophy, learning, psychology, sociology and technology. In addition, practical applications of the actionable insights in this paper, in a form of strategic and operational frameworks or case studies, can be another pragmatic endeavor by practitioners and researchers.

Herwix et al. (2022) highlighted the importance of more serious and systematic engagement with the selection, framing and prioritization of ethical issues. There is an emphasis among the state-of-the-art for the need to be more aware, anticipatory, reflecting and informed about the variety of perspectives and contemporary debates concerning AIED ethics. In particular, the relevancy and idiosyncrasy to assessments in our study can help bring forward distinctive actionable applications in this realm.

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Development of Flipped Teaching Method in Fluid Mechanics Class utilizing OpenFOAM

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Abstract

Fluid mechanics class is a specialized basic subject in engineering education that is difficult to learn for technical college students and to earn the class credits, the study of students on fluid mechanics is easily limited to taking only the form of partial differential equations into account, and there is a problem in the quality of education that students are not able to understand and apply their knowledge of fluid mechanics very well.

In the flipped classroom, students prepare for new learning content by watching video lessons at home, and there is no lecture in the classroom. On the contrary, the teacher gives individualized instruction to each student on assignments that would traditionally be considered homework, and students work on them in collaboration with other students.

Since significant learning results can be expected from active and self-directed learning through active learning in flipped classrooms, it is assumed that flipped classrooms will gradually spread through experimental efforts, especially since it is considered to be a learning method compatible with online learning in the post-COVID-19 era.

The purpose of this study is to introduce OpenFOAM that is a free software for fluid analysis into the flipped classroom, which has been attracting attention in the field of education, in response to the question of quality assurance in fluid mechanics classes in technical college education, and to find out how the simulation results of fluid phenomena visualized by students themselves can be connected to theoretical knowledge of fluid mechanics. From this educational practice in technical college, we aim to develop a remote flipped learning method to draw students' interests and make them feel "interested and want to know more" by introducing the OpenFOAM into fluid mechanics class.

In this paper, we introduce a practical case study of a fluid simulation theme using OpenFOAM at Hiroshima College, in which students were asked to simulate fluid dynamics on their own by trial and error, following the operation manual of OpenFOAM, even though they know less about theoretical knowledge of fluid mechanics.

Keywords: *Fluid mechanics, Flipped classroom, Active Learning, OpenFOAM.*

Introduction

Of the four major mechanics subjects (fluid mechanics, material mechanics, thermodynamics, and machinery dynamics) related to mechanical engineering, it is often said that fluid mechanics is the subject with the highest hurdles for students. In particular, it can be said that it is very difficult for technical college students, who have graduated from secondary education and receive a five-year integrated engineering education from the age of 15, to understand the partial differential equations of fluid dynamics.

This is probably due to the following reasons. In junior high school before entering technical colleges, the concepts of force and motion, as well as static fluids such as gas and buoyancy, are emphasized as science content. Mechanics of materials and dynamics of machines are subjects that students are familiar with as an extension of mechanics of mass points and rigid bodies, and thermodynamics itself is learned in detail in upper-grade physics. On the other hand, in matters related to fluid dynamics, pressure, buoyancy, and air resistance are one of the various forces that are learned in ``basic physics", which is the elementary content of physics, but more detailed content is covered. The ``Physics" you learn does not go beyond this. In addition, water and air, which fluid dynamics is concerned with, are not bodies with a fixed shape that appear in general mechanics, but they move and transform with velocity and acceleration. It can be inferred that the point of how to handle such motion of an object mechanically is also a big hurdle for beginners.

Furthermore, in material mechanics and thermodynamics, it is possible to obtain results that do not deviate greatly from the knowledge obtained from daily experience, even without knowing the details of the subject. In contrast, there are many phenomena in fluid flow phenomena that are opposite to common knowledge (assumption), and while this is an interesting aspect of fluid mechanics, it is also the reason why students have a sense of dislike for the subject.

In particular, the governing equations of fluid mechanics, unlike those in other fields such as material mechanics, thermodynamics, and machinery dynamics, use the so-called "Eulerian" method of observing the space through which the fluid passes, rather than the familiar "Lagrangian" method of tracking and observing the fluid in motion in time (which is where the partial differential equations come in), so it is quite difficult to understand the physical meaning of these partial differential equations.

In the end, the students of technical colleges tend to neglect the fluid mechanics class as a specialized basic subject in engineering education. In addition, to earn course credits, the study of fluid mechanics is limited to taking into account only the form of partial differential equations, and there is the problem of the quality of education in which students are not able to understand and apply their knowledge of fluid mechanics very well.

Objective

The purpose of this study is to answer the question of guaranteeing the quality of the fluid mechanics classes in technical college education, by using OpenFOAM, a free software for fluid analysis, to link the simulation visualization results of fluid phenomena obtained by technical college students themselves to the theoretical knowledge of the thermal fluid mechanics class content. The purpose of this study is to practice engineering education which draws out the interest and motivation of technical college students and makes them feel that it is interesting and they want to know more about it.

In this paper, we introduce a case study of simulation research of fluid dynamics using OpenFOAM in graduation research of Hiroshima College of National Institute of Technology (KOSEN), in which students of the technical college were asked to perform simulations of thermo-fluid dynamics by trial and error, following the operation manual of OpenFOAM and other software on their own.

What is OpenFOAM?

OpenFOAM stands for Open Source Field Operation And Manipulation. This is an open-source software version of the commercial code FOAM (Field Operation And Manipulation) developed and sold by OpenCFD (currently ESI) in the UK. OpenFOAM is a set of physical field calculation codes developed in the object-oriented language C++ and can be used in the field of continuum mechanics such as computational fluid dynamics (CFD), solid stress analysis, and financial engineering.

Computational Fluid Dynamics is becoming an essential tool in various engineering fields. However, it is expensive to suddenly introduce commercially available fluid dynamics analysis software. Therefore, OpenFOAM, open-source software that can be easily used by people in universities and companies, has been attracting attention in recent years. OpenFOAM can be introduced free of charge and has the advantage of being able to perform large-scale analysis regardless of the number of licenses.

However, since OpenFOAM is free software, there is an operation manual but no official support. In addition, there are no default values for various calculations, and it is necessary to think about the initial values to be set by oneself the operation is performed by CUI (command-based), which is a high hurdle for beginners.

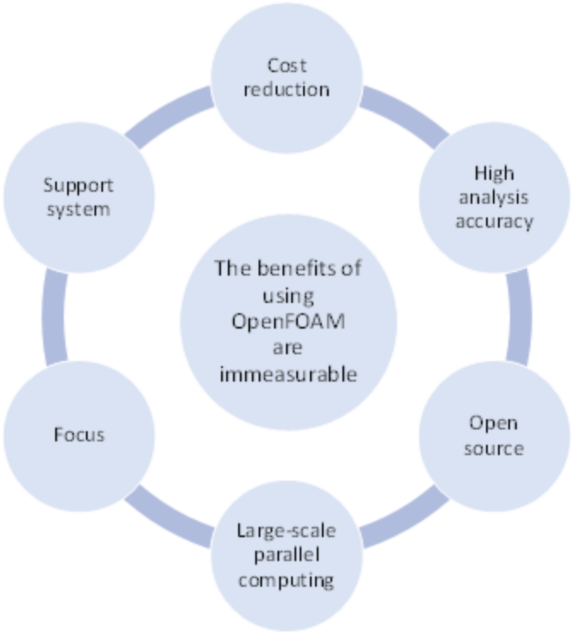

Figure 1 shows the features of OpenFOAM.

Figure 1 shows the features of OpenFOAM. Firstly, since commercial CFD requires high maintenance costs, you can take advantage of the benefits of open source to reduce costs. Secondarily, high-accuracy and state-of-the-art solvers proven in universities and research institutes can be used. Thirdly, It's open source, so you can validate computational algorithms and embed solvers for new physics models. Fourthly, You can use HPC and cluster parallel computing by OpenMPI for free. Fifthly, OpenFOAM is getting more attention, so you can use OpenFOAM on supercomputers at a reasonable cost. Lastly, more and more organizations and researchers are supporting and customizing OpenFOAM since 2004.

Simulation of thermal fluid in a boiler furnace

As a special graduation research theme1) of the Advanced Course of Maritime System Engineering at Hiroshima College of National Institute of Technology, "Simulation of thermal fluid in a boiler furnace by OpenFOAM" was carried out in 2018. In this study, we visualized the thermal fluid and temperature distribution in the boiler furnace by computational simulation and identified the causes of adverse effects such as heat concentration in the piping inside the boiler and adhesion of coal ash to the heat transfer surface. We aim to improve the efficiency of the system and improve points for long-term safe driving.

1 Governing equations and computational algorithms

In OpenFOAM, when dealing with temperature, it is generally treated as a compressible fluid. Only compressible solvers can handle thermophysical properties. Fluid and heat transfer equations are described by differential equations. Governing equations include the following.

- Equation of motion (Navier-Stokes equation)
- Continuity formula (conservation of mass formula)
- Energy equation (energy conservation formula)

The equation of motion and the equation of continuity describe the motion of the fluid, and the energy equation describes the phenomenon of heat transfer.

In a compressible fluid, it is necessary to use the equation of state to obtain the density. When the fluid is gas, the ideal gas (perfect gas) equation of state is often used. It is also necessary to consider buoyancy and turbulence models depending on the flow field conditions.

The algorithm that simultaneously calculates the fluid equation of motion and the equation of continuity uses the pressure-velocity coupled method.

There are SIMPLE methods, the PISO method, the PIMPLE method, etc. for the pressure-velocity coupling method, but the OpenFOAM steady-state analysis solver uses the SIMPLE method as the pressure-velocity coupling method. The SIMPLE method is calculated according to the procedure shown in Figure 2.

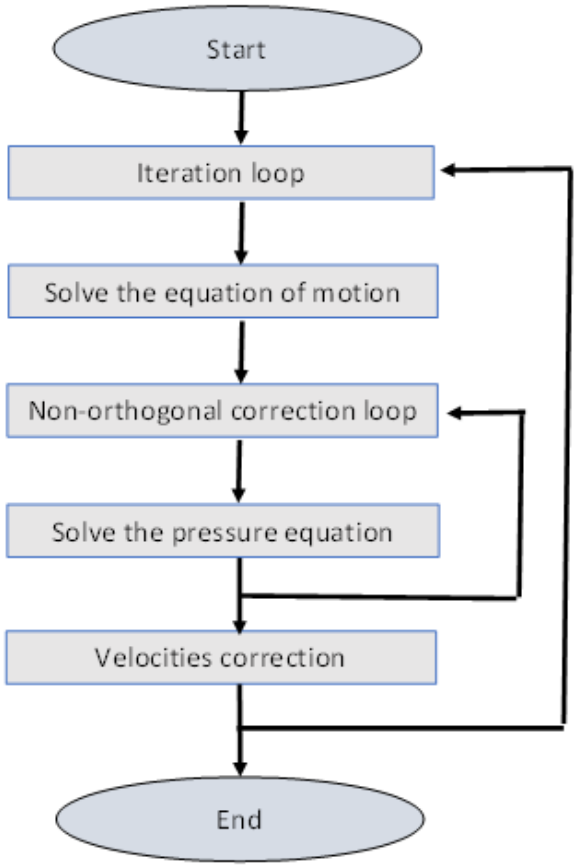

Figure 2 SIMPLE method calculation procedure

As shown in Figure 2, the calculation procedure is as follows.

(1) Give the initial and boundary conditions of the flow field.

(2) Solve the equation of motion (N・S equation) to obtain a tentative velocity.

(3) Solve the pressure equation derived from the continuity equation by the SIMPLE method, or the pressure equation from which the time differential term is omitted, and obtain the pressure.

(4) Calculate the corrected velocities from the equation of motion and update the velocities.

(5) Repeat the above calculation of pressure and update of velocity for a specified number of times.

(6) Repeat the above procedure until the calculation residual of the continuity equation becomes small.

Repeat the above procedure for the required time steps.

2 Analysis model and calculation results

Based on the drawing data (Figure. 3) provided by the electric power company, the boiler furnace model to be analyzed is 10m wide (15m wide at the top of the boiler), 20m deep, and 60m high radiative reheat variable pressure once-through boiler. Assuming a furnace, a model with a simple shape was created using FreeCAD (Figure. 4).

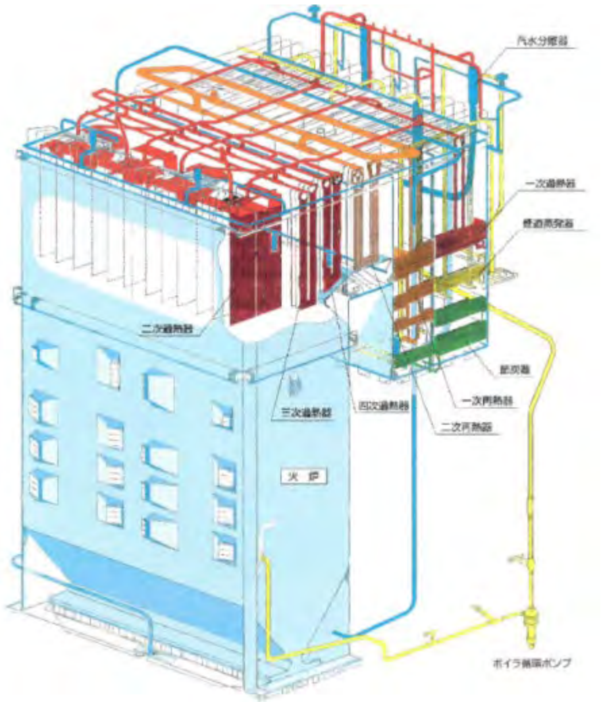

Figure 3 Drawing data provided by the electric power company

Figure 5 shows the computational mesh. The dimensions of the model are width: 16 mm (from the upper part of the boiler to the inlet on the right side), depth: 20 mm, and height: 60 mm. The division number of blockMesh is 36×44×124 (196416). The computational grid number is 145065. This boiler model has 16 inlets (burners) on one side, with a total of 32 installed facing each other. Twelve thick U-shaped pipes were installed above the boiler.

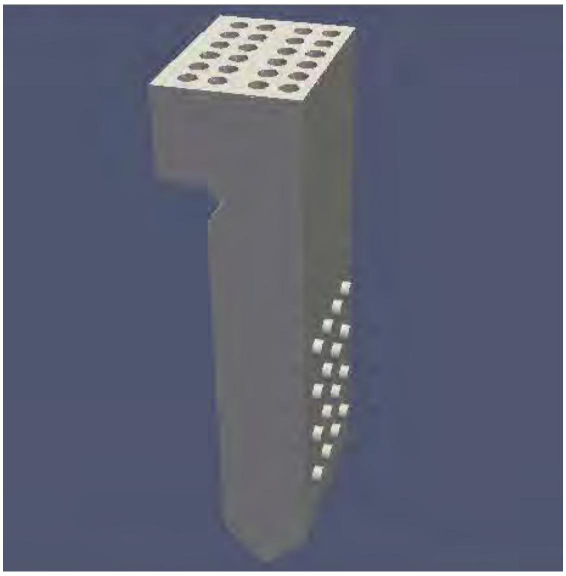

Figure 4 Creation of furnace model with FreeCAD

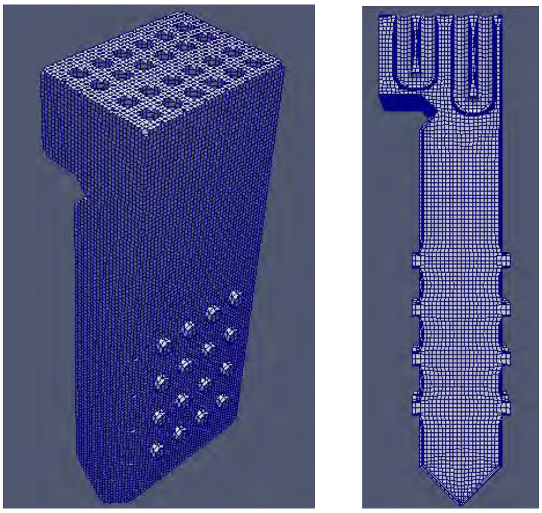

Figure 5 Creation of furnace mesh (overall view and sectional view)

Regarding the setting of calculation conditions, the right inlet is in1, the left inlet is in2, the upper left outlet is out, and the fluid is air. The setting conditions are as follows.

・Initial conditions: Inflow velocity: 0m/s

The pressure inside the furnace: 101325Pa (standard atmospheric pressure)

The temperature inside the furnace: 293K

・Boundary conditions: Inlet in1 velocity: 1m/s, temperature: 1500K

Inlet in2 speed: 1m/s, temperature: 1500K

Outlet out pressure: standard atmospheric pressure

Wall: Velocity is a non-slip condition, the temperature is wall insulation

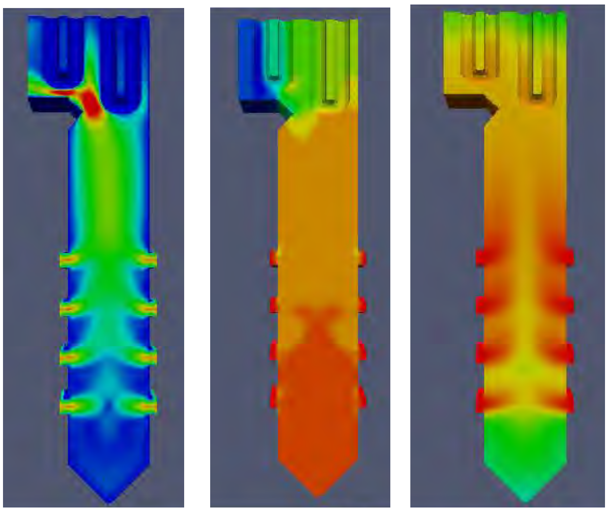

Figure 6 Velocity, pressure, and temperature in the furnace (cross-section)

In this study, the calculation conditions of the flow in the boiler furnace are different from the actual ones as a preliminary calculation. For example, calculation conditions that take into consideration the shape of the pipes and the circulation of boiler water on the walls and inside the pipes are not set. In addition, the only fluid in the boiler furnace is air.

Figure 6 shows the calculation results of the flow velocity, pressure, and temperature distribution of the thermal fluid in the furnace. From the calculation results, it can be seen that the velocity is high and the pressure is low where the cross-sectional area of the flow path is small due to the constriction of the pipes and upper part of the boiler. Since the calculation was performed on a notebook computer, the calculation time was short and the accuracy was not sufficient, but it is considered that a reasonable calculation result was obtained.

Simulation of the flow around the car body

We had students work on "The fluid simulation around the car body" as a graduation research[2)] of the Department of Maritime Technology of Hiroshima College in 2019.

Since the governing equations and calculation algorithm for this calculation are almost the same as those described above, only the analysis model and calculation results are introduced below.

In this research, we wanted to approximate the actual shape of a passenger car, so we downloaded the STL file of the car body and used the one with the tires retrofitted. Also, I tried not to make a gap in the body model. The model dimensions are 4.6m in length, 1.8m in width, and 1.3m in height. Solidworks was used to create the model.

Here Xsim[3)] was used to create the mesh. Xsim is a web-based preprocessor for OpenFOAM that allows you to copy the case directory needed for calculations in the tutorial and change the values and calculation conditions. By using this, you can easily create a case file.

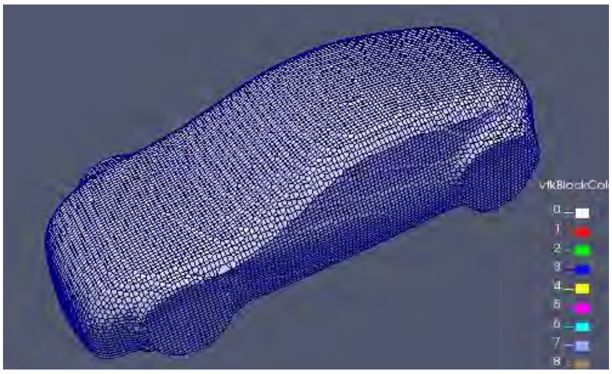

Figure 7 Creation of 3D shape model and mesh generation of car body

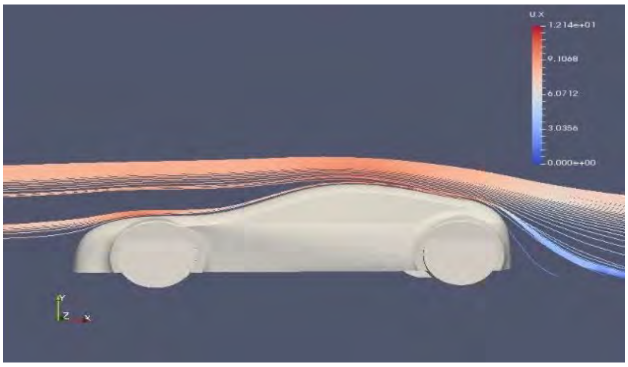

Figure 8 Streamlines of flow around the car body (from the side)

Figure 9 Flow pressure distribution in the center cross-section of the car body

Figure 7 shows the 3D shape model and mesh generation of the car body created using Solidworks and Xsim.
The calculation conditions are set as follows.

・ Initial conditions Speed U = 8.6 m/s, pressure: standard atmospheric pressure
・Boundary conditions Velocity U = 8.6m/s, pressure P = 101325Pa
Body and ground: no-slip conditions
・Regarding calculation parameters
Calculated Courant number = 0.9
Calculated Reynolds number = 109861
Number of computational grids = 30000

Figure 8 shows the streamlined pattern (side view) of the flow around the car body visualized from the calculation results for a calculation time of t = 5 seconds. The color indicates the velocity magnitude (m/s), and the maximum velocity of the flow near the car roof was found to be U = 27 m/s.

Figure 9 shows the flow pressure distribution in the center section of the car body. The color indicates the magnitude of the flow pressure (Pa), and it was found that the flow pressure is small where the velocity is high (around the car roof) and the flow pressure is large at the front of the car.

As shown in the simulation visualization above, it can be said that reasonable simulation results were obtained from the streamlined distribution and pressure distribution of the flow around the vehicle body.

In this graduation research, we used an ordinary DESKTOP computer (4GB of memory) for calculations, so the calculation time for dimensions was only 5 seconds and the number of calculation grids was 30000. However, if the calculation time and the number of calculation grids were increased, we think that more remarkable calculation results can be obtained.

Discussion and conclusion

This paper introduces the cases of graduation research using OpenFOAM conducted at Hiroshima College of National Institute of Technology (KOSEN), regarding engineering education related to thermo-fluid dynamics, which is a major subject in technical colleges.

At the beginning of the graduation research, the students of the technical college had little understanding of the partial differential equations and simulation knowledge, and they had conducted various flow simulations by trial and error, simply following the operation manual. The joy they felt when they were able to reproduce the flow phenomena on video was very impressive. Then, several technical college students transferred to universities to study the physical meaning of partial differential equations of fluid mechanics and acquire further advanced knowledge on how the invisible flow became so visible on the computer.

From these educational cases of so-called "flipped teaching," in which the results of simulation visualization of thermo-fluid dynamics lead to an understanding of theoretical knowledge of fluid mechanics, it was found that if a manual[4)] can be developed to easily operate

OpenFOAM, even if technical college students do not have sufficient basic knowledge of thermo-fluid dynamics or numerical simulation, they also can use OpenFOAM to carry out numerical simulation of flow phenomena and learn and deeply understand essential meaning of fluid mechanics. In the future, we plan to continue this research on educational practices to enhance the learning effect of fluid mechanics by using flipped teaching method utilizing OpenFOAM.

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Incorporating GLH Attitude into Physics-class Improvements with Small-step Method and DCAP-cycle Method

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Abstract

In the form of "Do, Check, Action and Plan" (DCAP-cycle)-evaluation processes, my teaching practice and improvements will be presented. Towards a unified and essential understanding of physics, we have to know students' learning status. First we have to know how to seize students' learning minds and motivate them to learn physics by demonstration (or experiment) and making students look into daily seen physics phenomena, and have successive question-and-answer dialogues with them. Some parts of complex demonstrations pre-recorded as movies are also shown after it to make students' insight more focused. Do part: Based on the demonstration, fundamental formation of basic notion of physics begins through question-and-answer dialogues between a teacher (instructor) and students. Through the dialogues an instructor can sense the students' learning status and decide the effective starting points to teach physics, such as how to introduce main topics and review of already learned (pre-required) materials of past grades. Check part: The evaluation of students is based on midterm and final examinations, which are analyzed in terms of causes of wrong answers. The analysis lead us to find small-step instructions on how they would understand the right notion in a logical order without replacing understanding physics with meaninglessly remembering series of formulae of physics. Action part: After taking questionnaires of students' opinions, I fed back to their opinions and made some concrete suggestions intended for their modification to the right studying attitude. Plan part: I will present next years' instructional design of physics all with my 14 years' teaching experience of physics in conjunction with the results of former Do-Check-Action of experience of teaching physics, reinforcing the pre-required notions. Every small-step instruction is originated from the analysis of students' learning status.

Keywords: *systematic physics class improvements, GLH attitude, small-step method, DCAP-cycle method*

Introduction

It is a long-pursued challenge for every physics teacher to make students properly understand the basic notion (definition) of physics, accommodated with intuition based on experimental experiences (Fujii and Ohno, 2019). This paper includes a review of Fujii (2023) and improvements in terms of some new notions and classifications.

Recalling my physics class experiences when I was beginning to teach physics, I had had two instructional problems. One was a problem of teaching techniques, such as my inability to give students the precise idea of physics as I had intended, and the other was a problem of students' learning procedure in physics such as their difficulty in how to recognize and define a physics notion from a demonstrated physics phenomenon. In other words, the latter is related to the learners' difficulty in forming basic notions of physics. The causes of difficulty come from some aspects: students' poor learning status, such as lack of background knowledge of mathematical or arithmetical notions and lack of daily physics experiences that help intuitive interpretation of physics, and some mental barriers that prevent the perception of phenomena in physics.

Students within the scope of this report range from C (pass)-evaluated students to S (Very good)-evaluated students. In our school (National Institute of Technology, Tokyo College; in short we call it "NITTC", from now on), S,A, B and C –evaluations are recorded as passing final examination students and D-evaluation is recorded as students who are failing to pass. For simplicity, I discuss educational methods only for the successful (from C to S -evaluated) students.

My fundamental educational attitude is based on the advice from my supervisor at the old workplace, that is *"Grow Lower (poorer) and Higher (better) understanding students in the same physics class and at the same time",* calling this *GLH attitude* from now on. Honestly speaking to realize the *GLH attitude* sounds like a difficult thing to achieve. But with the scope of higher and lower understanding students, the *GLH attitude* makes us examine whether presently taught physics way of thinking is clear enough for students with different levels of understanding physics. Such self-criticizing points of view lead to improving physics classes more intuitively and deeply through dialogues with students. The *GLH attitude* shall take on every method in the daily trial-and-error practice in this paper.

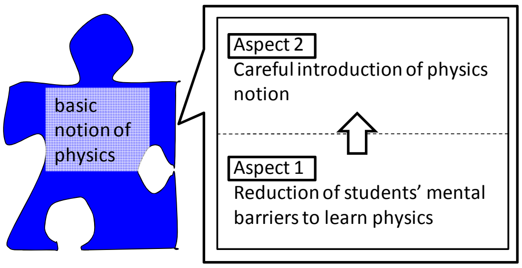
For sustainable improvements in physics class, the Do, Check, Action, and Plan cycle self-evaluation method is appropriate, which is called the "*DCAP-cycle method*" from now on. In general, the method has recently been tried to be used in practical business fields to adapt working staffs to rapidly changing social situations, while the usual PDCA-cycle method is used to improve an ordinary work routine without rapid changing. Therefore, the DCAP-cycle method has the advantage of fitting educations to rapidly changing students in the new era, with some problems on how to learn. Note also that the DCAP-cycle method can be accommodated with trial-and-error improvements.

To incorporate *GLH attitude* with physics education, let us ask "how can we face and release students' difficulties?" The answer is to separate the difficulties into smaller achievable parts, (see Shimamune, 2008). This separation enables students to increase the number of successful experiences and learning motivations, calling this the *"small-step method"* from now on. Besides, the method reduces the mental barrier against considering physics in many contexts, such as experimental settings, meanings, definitions and the laws in physics.

In this report, I will include the present class practice combined with the *GLH attitude*, the small-step method, and the DCAP-cycle method. In materials and method section, we mainly report the "Do"part and then the "Check"part, the "Apply"part and the "Plan" part are explained; in results and discussion section an overview is presented and conclusion follows.

Materials and Methods or pedagogy

To incorporate the *GLH attitude* into daily physics class practice, two aspects (see Fig.1) are necessary; aspect 1: reduction of the students' mental barriers to learning physics itself and aspect 2: careful introduction of physics notions. Although reviewing pre-required materials is sometimes important, they will be discussed later. One theme of a physics course is composed of many pieces of basic notions of physics. To make each piece firmly understood these two aspects of teaching physics are important. In Figure 1, a rough schematic to form a piece of a basic notion of physics is shown.



GLH attitude of instructional design

Figure 1.Two Aspects to Form Basic Notion of Physics.

Combining the two aspects obtained by the small-step method, we can gradually introduce concrete materials by confirming students' learning status through dialogues between students and instructor (teacher).

The small steps to realizing each aspect are summarized as follows: for the mental barrier reduction (aspect 1), three small steps can be introduced.

Table 1. Small Steps in Mental Barrier Reduction.
Step1. Intuition formation: expressing notions in words
Step2. Physics situation sharing by demonstration
Step3. Linking intuition and demonstrations

Step 1 is intended for students who are obsessed with an inferiority complex in physics. To reduce their mental barrier to physics, at first expressing a new notion in words can give students its intuitive meaning. Secondly giving daily-life examples corresponding to the new notion is important. Gradually they get used to the setting of physics. Sometimes, we need to choose the simplest and shortest phrase to explain the situations more intuitively. This step is rephrased as "Grab students' minds."

In step 2, after the reduction of mental barrier in step 1, even students who are poor at physics begin to expect to understand physics a little. Then we can go to demonstration. The demonstration is not merely a scientific performance anymore; it has practical meaning for motivated students. The students begin to share the experimental setting and they are prepared to learn the corresponding theme of physics.

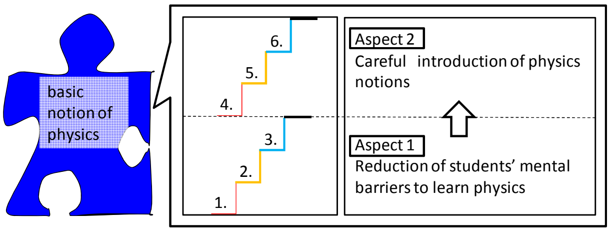
In step 3, the meaning of the demonstration can be explained. Now, students roughly see how to extract physics notions from it. Thus, the relationship between the demonstrations and intuition can be introduced. Question-and-answer dialogues with students are good chances to modify some misconceptions, and we can provide feedback of the above steps 1,2 and 3 to them.

For the careful introduction of basic notions by the small-step method (aspect 2), instructions are divided below.

Table 2. Small Steps for Exact Expression.
Step4: Writing down qualitative expressions
Step5: Experimental confirmation of the law
Step6: Linking mathematical expressions (definitions) and experiments

Although the smaller steps of steps 4, 5 and 6 are ordinary teaching procedures in physics, especially in step 4, in order to prepare students to introduce mathematical expressions in physics class, an intuitive approach using schematics is useful. As we have already introduced the relations between notions translated in words, intuition, and experiment in steps 1, 2 and 3, the step 4-procedure now works well.

In steps 5 and 6, after students' experiment they themselves confirm the law of physics. Then the definition, that of physics, experimental results are unified in students' minds as in Fujii and Ohno (2019).



GLH attitude of instructional design

Figure 2. Two Aspects and Each Small Step to Incorporate *GLH Attitude.*

As in Figure 2, understanding the basic notions of physics can be symbolically shown as a piece of a jigsaw puzzle. A collection of the pieces (basic notions) is metaphorically expressed as the essential and "unified" (inter-related) understanding of physics, for example see "trinity of science", (Fujii and Ohno, 2019).

Based on the above methods, we will show the practice of physics in the DCAP-cycle method in the next parts. Before showing DCAP-cycle class practice, let us define "qualitative understanding", as a skill with which students can roughly predict a changing tendency of measured quantities by observation and which can make intuitively grasping phenomena possible.

"Do" part

The number of my physics class practices (90 minutes per class) amounted to 40 in the 8 years' education at NITTC, and my teaching experiences are summarized here. Even for the introductory level of wave physics class for the 3rd grade students, pre-required materials in mechanics should be introduced in addition to the ordinal-instruction model (see Fig.1 and 2). After the mental-barrier reduction (aspect 1, see Table 1), smaller-step instructions (aspect 2, see Table 2) with the review of pre-required materials (see piece 0 in Fig.3) in their necessity, are shown below.

Especially keeping the *GLH attitude*, we aim to have students understand the principles of physics. Such essential and unified understanding of physics can be promoted by linking intuition, definition, experiments and mathematical expressions altogether using question-and-answer communications. In this class, instructors and students both ask questions. Instructors' questions work as an introduction of notions, and ones from students, why- and how-type questions, focus what are essences of the notions. In fact, students' questions range from the confirmation of the present experimental setting, the definitions of physics quantities, to essential questions such as the discrepancies between the laws (or notions) of physics and their naive expectations, leading us to notion-sharpening points of view. The (S, A, B and C-evaluated) students can ask questions anytime in class. This means that regardless of the depth of understanding (or evaluations), many students are able to challenge themselves to understand the principles by asking questions. This is the Q&A-realization of *GLH attitude* in physics class.

To implement the small-step method with *GLH attitude* into a real physics class, we need modifications. As in Fig.3 the modification is to add a "piece 0", the introducing of pre-required materials. With reinforced background notions through the introduction of pre-required materials (piece 0), more students can be ready for accepting the basic notion of physics (piece 1). And we just follow the ordinal-instruction model; aspect 1:the reduction of mental barriers, and then the aspect 2: the careful introduction of basic notions with the small-step instructions.

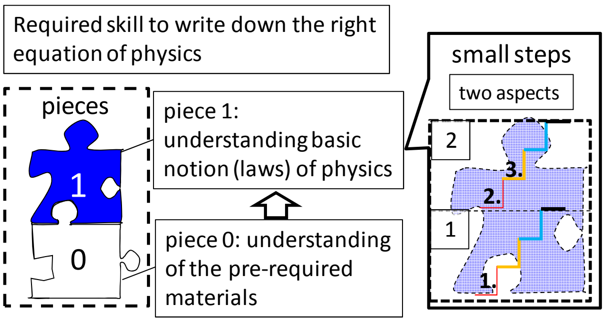


Figure 3. Implementation of Small-step Method into a Real Physics Class (Modification of Fig.2).

Let us show the above implementation in concrete class practice for wave phenomena. As piece 0 (see Fig.3), pre-required materials in mechanics are reviewed, such as equilibrium of applied forces, the equation of motion, uniform circular motion, and harmonic oscillation. And as the aspect 1 in piece 1 (the reduction of mental barriers), a simple circular motion demonstration tool (a tennis ball connected with a kite string) is used as an icebreaker in physics class. Successively, the definition in words (step1 of aspect 1, see Table 1) and its meaning through a demonstration or self-made physics demonstration video for more complex experiments are explained (step 2 of aspect 1). And the link between definition and demonstration is explained (step 3 of aspect 1, see Table 1). A qualitative understanding of physics thus proceeds (see Table 1).

Now that students roughly understand the basic notion, more exact mathematical expression can be acceptable for them. Thus we will go through a careful introduction to build equations of physics properly (step 4 of aspect 2in piece 1, see Table 2). To realize step 4, we can divide step 4 into smaller sub-instructions.

Table 3. Sub-instructions for step 4 (Table 2).

Step 4a: Information classification by schematics
Step 4b:Direction (signature) and unit confirmation
Step 4c:Meaning confirmation by linear graph

Especially, in linear graph of step 4c (see Table 3), the information of slope and intercept of the graph plays a crucial role to check the meaning of equations. Thus, based on intuitive understanding of definition in words (step1 in aspect 1, see Table 1), the schematics-based signature-unit and graph confirmation, the above double-checking of the equation building process is reinforced and students thus can get accustomed to a quantitative way of thinking.

From here, taking the pre-required material, that is equation of motion as an example of piece 0 (see Fig.3), we apply the small-step method into ordinal practice.

Even for pre-required material we sometimes need to apply the small-step method. One is *"translation of equations into words"* (step1, see Table 1). By this procedure, more students would be familiar with equations in physics, so that they could write down equations in physics more precisely without memorizing by rote. Next one is "distinction of quantities based on basic SI system of units".

Newton's equation of motion "mass × acceleration=resultant force", can be translated into a sentence, "When the sum of exerted forces are non-vanishing due to the resultant force remaining, an object with mass *m* [kg] keeps being accelerated in the same direction with the resultant force". With this translation, students begin to understand the meaning of the equation, the purpose of using it and how to use it.

But for students, to be able to write down Newton's equation of motion properly, mere translation is not enough. Problems of misinterpretation of mathematical expressions remain. First the problem comes from the unit in-distinction of forces; the second one comes from the misconception of "*ma*", which is *not* a part of resultant force but *moving state* expressed by unit [N] (Newton) for static observer. And the third one comes from proper direction encoding into signature based on a schematic compared with positive axes directions. Rarely, step 4b needs to be modified as follows.

Step 4b: Distinction of variable symbol and unit name. For example resistance *N*[N], that of *m* [kg] and *L*[m] should be recognized with right pronunciation.

"Check" part

In terms of sustainability of these physics class improvements, it is realistic to make use of usual midterm and final examination evaluations.

In order to evaluate students' understanding of physics class through examinations, description-type problems include much richer information about students' status than multiple-choice problems. We can guess the origin of students' inappropriate logic and can know how deeply they understand the particular theme of physics.

After marking the physics examinations, we can see that most of the students reach the goal in the sense that they can get more than 60% evaluation (C,B,A and S-evaluation) based on the results of examination (75%) and handouts (25%). Class improvements can be reduced to polishing present instructional design[1]with the small-step method and DCAP-cycle method while keeping *GLH attitude*. For the further improvements, after the analysis of description-style examination, students' weak points are found. Then basic review prints are given, and extra question-and-answer class is practiced after-class for the D-evaluated students. Examining the results, they are reflected to sharpen instructional design (plan) in the next year. Additionally, the questionnaire and dialogues as well as their feedback, shall be shown in the next "Action" part.

"Action" part

In this part, we introduce a questionnaire, its analysis and feedback to students, which actually works as a sort of dialogues between students and the teacher (instructor). The questionnaire is composed of multiple-choice questions and a free-style description part commonly taken in Microsoft "Forms" platform in NITTC. In this paper, we focus on the analysis and feedback of the free-description part.

In the questionnaire, "the quantity of physics homework is too much" for many students. This result can be interpreted in as the gap problem between teacher and students. On the one hand, students want to study as *efficiently* as possible, on the other hand the physics teacher wants them to study *effectively*[2]in order to have essential and unified understanding in physics. The necessary instructions range from mastering pre-required materials to enhancing insight into phenomena, relating with law in physics and their mathematical expressions. As I had been worried about their unsuitable way of problem solving since homework checking, I fed back to students as follows:

The purpose of problem solving is *not* merely increasing the number of solved problems, but the reinforcement of the foundation, such as the confirmation of forgotten definitions of basic notions, meaning of the quantities of physics and background in physics and experimental settings. As the second step, the purpose of problem solving is to broaden the range of applications of the laws. As we *cannot assume that every student as the same ability* in physics, we *don't need to do homework in the same way as other students*, which is rather inappropriate to enhance your ability to consider physics. In this way I was able to suggest changing their way of doing homework.

The way of doing homework is summarized below.

Table 4. Small-step procedure for Homework.

Step A: Solve the definition-confirmation level problem first. If having any difficulty, review the corresponding part of the physics text book.

Step B: Pick up some typical and a minimum number of problems. And concentrate to solve the problems as perfectly as possible, including the review of pre-required field of physics.

Step C: After step B is examined enough, then solve similar but different setting problems.

If the basic notion is well established, solving more difficult problems can enhance students' ability.

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[1] As referred, methods for growing D-evaluated students are out of the range of this paper, due to much more trial-and-error approaches needed for their analysis.

[2] In most cases, the quality of learning is ignored by "efficiency-oriented" students. *Efficiency and effectiveness in learning are not compatible* practically.

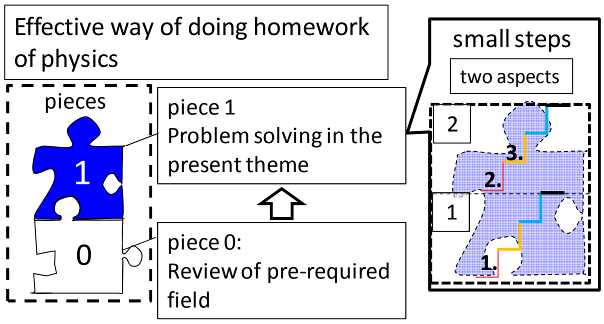

Figure 4. Small Steps for Learning by Homework.

"Plan" part

As the rest of DCAP-cycle method with all the above results of DCA-cycle, next year's physics instructional design are shown below.

Plan: Towards physics class easier and deeper to learn

Steps 1,2 and 3 below aim to forming qualitative understanding of physics notions.

Step 1: Expressing basic notions in words relating daily-seen phenomena, removing misleading (similar) concepts from the students' misunderstood definitions of the basic notions. The translation from equation to words is also introduced as the review of pre-required materials.

Step2: Starting from simple demonstrations, communicate with students on naive questions "why and how?" and their answers by dialogues, forming a rough description of basic notions of physics.

Step 3: Linking intuitive interpretation, experimental experiences (demonstrations) and definitions.

Steps 4,5 and 6 aim at the careful introduction of quantitative (mathematical) expression of physics.

Step4: Make students feel like listening and make use of examples, demonstrations and self-made videos.

Step5: Visualize and define quantities in physics using schematics, graphs and equations, reviewing the meaning and basic SI system of units of the slope and the intercept in a linear graph. Concretely, examining schematics and graph can be small-step instructions, such as the distinction among velocity, acceleration and force vectors, drawing force vector properly with a point of exerted force only on the object, recognizing positive direction of coordinate axes, signature-decoded direction and direction-encoded signature with the positive axes directions.

Step6: Build proper equations of physics, linking relations with experiments, considering deeply.

Optional plan

Steps 1 and 2 aim to cover pre-required material. Introduce them when they are in need.

Step 1: The distinction of units of "similar" quantities

For example, momentum mv[kg m/s], accelerated state ma[kg m/s^2]=ma[N], kinetic energy $1/2mv^2$[kg m^2/s^2]= $1/2mv^2$[J] tend to be confused by students poor at physics. At least the distinction of units can give a good starting point to recognize the differences between these "similar" concepts.

Step 2 : The distinction of basic notions of physics in words by comparison between them.

For example, the word "work" or "force" are similar in Japanese but completely different in physics.

Coaching plan for students (see Table 4, Fig.4)

Following steps A, B and C (see Table 4), below attentions to students are fruitful.

Step 1: Habituation of note-taking in physics class

Step2: Visualization of setting by schematics even during homework.

Step 3: Making the right equation and practice it in homework reflecting on proper logical steps.

Results and Discussion

The separation of single themes of physics into smaller instructional materials, can be a good starting point to attract and reinforce students' learning minds. Combined with question-and-answer dialogues in class and the wrong-answer analysis based on the results of the description-style examination, a more concrete approach can be possible.

Especially, graph interpretation with distinction by basic SI system of units, such as tangential slope and the intercept, is essential because most of the important notions of physics are defined as changing rates.

Conclusions

The student-oriented instructional design are concretely shown in this paper. The answer to the question "How can we grow students in a practical sense?" while keeping *GLH attitude* is, to "start from facing students' difficulties and draw the instructions in need from students themselves. In other words, the *GLH attitude* makes us analyze their weak points in daily-life opportunity and naturally leads us to the small-step method and DCAP-cycle method.

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INTRODUCTORY PROGRAMMING EDUCATION USING SCRATCH AND JAVA

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Abstract

In the National Institute of Technology (KOSEN), Nara College curriculum, we teach programming to students in grades 2-4. The unit of programming is 6 credits in total. Students learn the Java language for the first two years. Students learn C language in the last year. In other lectures, students may also use other languages, such as Python and C#, for experiments and exercises. In this way, in the curriculum of this department, we teach programming firmly, but it cannot be said that students have programming skills. As a cause of this, a certain number of students are not good at programming at the stage of the lower grades. We consider that students should submit assignments and pass exams instead of actively learning to program. Therefore, to dispel students' weak perception of programming, on the other hand, for students who have advanced understanding, we will change the tasks according to their proficiency level so that they can challenge more advanced problems. This is possible by having multiple instructors conduct classes, and there were problems such as difficulty in evaluating students by dividing them according to their proficiency level. Therefore, we gave a lecture using Scratch and the Java language in the Introduction to Computer Programming class held in the second grade, which is the first introductory education, and we report the details in this paper. In this class, the following procedures were carried out to help students to understand the control structures that they should learn first: Sequential processing, Conditional branching, and Iteration. (1) Visual programming (Scratch). (2) Java language programming. (3) Application problem. We teach classes with (1) to (3) as one set. This was not just a matter of teaching grammar and doing exercises, but to help students understand and maintain their motivation. We compared and considered the results of classes conducted using this method for the first four years from 2019 to 2022 with classes conducted using only Java. Although the time required to teach grammar content was shortened compared to the conventional class method that taught only Java, the grades did not deteriorate compared to before, and it is suitable for classes to learn Java language and C language from the second and third years. There were no major issues.

Keywords:
Programming, Introductory Education, Scratch, Java

1. Introduction

In 2020, programming became compulsory in elementary schools, and programming education started in elementary school. Among them, "Acquiring the ability to understand and use computers well is important for children living in the future society where computers are required to be used in all activities. It is extremely important even if I get a job." [1] Reference materials have been published for this purpose [2]. It uses visual programming languages such as Scratch [3] and Viscuit [4]. At Nara College of Information Engineering, we have implemented programming education as part of our curriculum. We also found out that there are students who are not good at programming, other than students who are interested in programming. In response to this, we have taken measures such as setting tasks by proficiency level, but we have not seen any significant improvement.[5] Therefore, we considered seamlessly connecting logical thinking and programming languages and using visual programming, which is familiar in elementary schools, in the introductory programming education of Nara College of Information Technology Department. In this paper, I report the contents of the implementation and hope that it will be of help to future programming education in technical colleges.

2. Curriculum

We design specialized subject curricula. The curriculum consists of hardware, software, network, and information security fields.

Programming is positioned in the software field. Students learn programming in grades 2-4[6]. Table 1 shows the number of credits and grades for programming subjects. We teach programming introductory education in the Introduction to Computer Programming class.

Students learn the Java language for the first two years. Students learn C language in the last year. In class, students may also use other languages, such as Python and C#, for experiments and exercises. In this way, in the curriculum of this department, we teach programming firmly, but it cannot be said that students have programming skills. As a cause of this, a certain number of students are not good at programming at the stage of the lower grades. We consider that students should submit assignments and pass exams instead of actively learning to program. Therefore, to dispel students' weak perception of programming, on the other hand, for students who have advanced understanding, we will change the tasks according to their proficiency level so that they can challenge more advanced problems [6]. This is possible by having multiple instructors conduct classes, and there were problems such as difficulty in evaluating students by dividing them according to their proficiency level.

Therefore, we decided to conduct a lecture using Scratch and the Java language in the Introduction to Computer Programming class that was held in the second grade, which was the first introductory education. This paper reports the contents.

Table.1 Number of credits and Grades

Subject	grade	Number of credits
Introduction to Computer Programming	2nd year, first semester	1
Computer Programming I	2nd year, second semester	1
Computer Programming II	3rd year, full year	2
Computer Programming III	4th year, full year	2

3. Lecture Structure

In this lecture, in the 15th week of the semester, we implemented a procedure to understand the control structures that should be learned first: sequential, branching, and iteration.

(1) Visual programming (Scratch)
(2) Java language programming
(3) Application problem

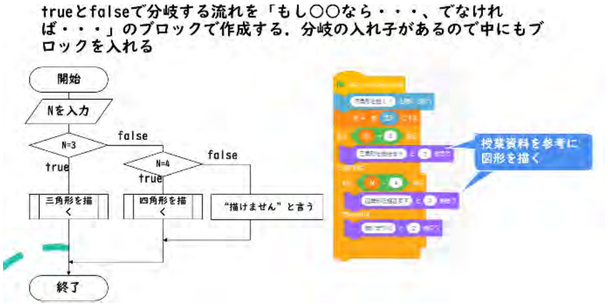
We teach classes with (1) to (3) as one set. This was not just a matter of teaching grammar and doing exercises, but to help students understand and maintain their motivation.

For example, Table 2 shows the contents of classes for the 2022 academic year. Except for guidance and comprehensive exercises, Scratch, Java, and application problems are given as lectures. Comprehensive questions are those in which students use what they have learned to solve problems. In addition, one part of the applied problems was studied in groups.

The lecture materials used were prepared by the instructor. Figure 1 shows an example of the lecture materials for the visual programming session. Fig. 2 shows an example of the lecture materials for programming using Java. The lecture materials were distributed to the students so that they could look back at them even after the project was completed. Scratch and Java lecture materials include flow charts and explanations to make them easier to understand visually.

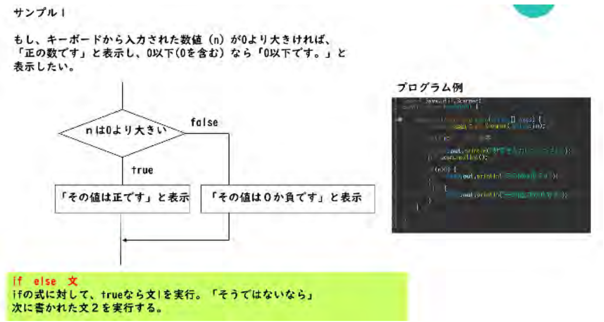
Table.2 Week and Lecture content (2022)

Week	Content
1	Guidance How to use scratch/How to use the Java development environment
2	Scratch: sequential processing
3	Java: sequential processing
4	Application problem, how to debug
5	Scratch: conditional branch, flowchart
6	Java: conditional branch
7	Application problem
8	Midterm Exam
9	Scratch: iteration
10	Java: iteration
11	Application problem
12	Comprehensive question
13	Comprehensive question
14	Comprehensive question
15	Final Exam
16	Test return, confirmation



trueとfalseで分岐する流れを「もし○○なら・・・、でなければ・・・」のブロックで作成する．分岐の入れ子があるので中にもブロックを入れる

Fig.1 An example of a lecture material (Scratch)



サンプル1

もし、キーボードから入力された数値（n）が0より大きければ、「正の数です」と表示し、0以下(0を含む）なら「0以下です。」と表示したい。

if else 文
ifの式に対して、trueなら文1を実行。「そうではないなら」次に書かれた文2を実行する。

Fig.2 An example of a lecture material (Java)

4. Results and Discussion

We compared the four-year course from 2019 to 2022 with the proposed method and the course from 2015 to 2018 taught students only the Java language. Since the Introduction to Computer Programming lecture is in the first semester, the lectures to be compared are also the same semester for second-year students. Therefore, we compared the results of the previous semester's classes.

Both lectures taught control structures, and they taught grammatical items excluding the Class structure.

The proposed method's grade standard deviation was 11.05-14.31 and the median was 77.0-95.8. On the other hand, in the conventional method, the grade standard deviation was 11.27-20.20 and the median was 70.9-79.5.

Although the teaching time for grammatical content was shortened compared to the conventional teaching method that teaches only Java, grades did not deteriorate sharply compared to before 2018. The median is rising. We considered this cause.

There are differences between full-year lectures and half-year courses, as well as different lecture contents and instructors, so a simple comparison cannot be made. A high median means that students performed well overall, even though the standard deviations do not differ significantly. We attribute this to the overall high performance of assignment submissions and exams. We believe that the easy-to-understand lectures and easy assignments for the students did not make them feel that they were not good at programming. Although we only teach the bare minimum of grammatical items, I thought that a virtuous cycle has been created in which students were able to research and learn on their own. I haven't formally taken a survey of students, but when I hear from students, they don't seem to have a strong sense of weakness. In addition, there is no problem in the following lectures on Programming I, Programming II, and III. Despite the short amount of time, it does not affect the grade.

4. Conclusions

Although the teaching time for grammar content was shortened compared to the conventional teaching method that teaches only Java, the grades did not deteriorate compared to before, and the result was a high evaluation. This is not accurate due to differences in faculty, exam questions, and the comparison between semester and full-year courses. However, we believe that low evaluations will foster a sense of inadequacy and that it will not affect the learning of the Java and C languages in the latter half of the second year and beyond. Also, students need to understand the control structure of the program.

It will be some time before elementary school students who have programming as a compulsory subject enter technical colleges, but we hope that the practical programming education that we provide at our school will help other technical colleges.

Future issues include the following. We have not been able to investigate whether students are not good at programming using questionnaire surveys. It is necessary to verify how much the number of students who are not good at it can be reduced by using the proposed method. Also, the time spent teaching Java grammar is reduced, while students need time for self-study to solve problems. Since this verification has not been done, this is a future task.

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EFFECTIVENESS OF PYTHON PROGRAMMING CLASSES USING PRE-EXISTING C PROGRAMMING KNOWLEDGE

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Abstract

An essential skill for information engineers is learning a new programming language based on ones they have already learned. In this study, a learning method is presented by practicing classes in which students learn Python by comparing it with the C language. Moreover, students are experienced this effectiveness. The students learn C language 6 months earlier. First, C code is presented to review the basics of the C. Next, the same and different points between Python and C language are explained. Then, Python code is presented. This allows students to efficiently learn new knowledge while using their pre-existing knowledge. This method enables them to use Python in a short period. We teach arithmetic, input/output, control statements (conditional branching, repeated statements), collections, and functions in eight classes. In order to evaluate the effectiveness of the method, we have confirmed the questionnaires done on the final class in the 2021 and 2022 academic year. The results are the following. First, more than 80% of the students have found the content appropriate or easy. More than 65% have felt that the learning speed was appropriate, and less than 20% have done that it was fast. More than 72% said that the comparison made it easier to understand contents. These results indicate that the transition of learning based on existing knowledge is realized in the class and that the students are able to experience the benefits of this transition. More than 88% of the students have felt that they understood the differences between C and Python, and more than 67% have done that their knowledge of C was deepened. Several statements about the perceived benefits of the comparison are identified in the feedback. The results of the survey indicate the following. First, this method allows students to experience the benefits of learning from comparison between new programming knowledge and understood one. Secondly, this allows students to learn new knowledge quickly. Finally, many students feel positively about this.

Keywords: *teaching methodology, programming, comparison, python*

Introduction

Numerous programming languages run various devices and systems in society. Each programming language has its own suitability. Hence, some programming languages are used vary widely depending on each company. In addition, new programming languages are created to meet the required applications, and old languages that have outlived their usefulness fall into disuse. Some languages have been in use for a long time. However, new features, syntax, etc. are sometimes added, so it is still necessary to relearn them. Hence, engineering students who want to work in the information field need to develop the skills to learn programming languages quickly.

An essential skill for information engineers is learning a new programming language based on ones they have already learned. One of the reasons is that understood knowledge can help them to understand the new language. the grammar of the new language will be able to be understood relatively quickly if concepts such as variables and control statements are similar between the learned language and the new one. The second reason is to clearly recognize the differences between languages. Knowing the differences between languages will make it easier to formulate ideas about which language to use when developing something. However, these are basically self-study methods. There would be few examples of classes that use one language as a base to learn a new language. We have not found no studies that show implementation in school. They are basically separated by class even if you're in a class where you learn two or more languages.

We have gotten an opportunity to teach Python with comparison. Therefore, A new learning method is presented by practicing classes in which students learn Python by comparing it with the C language. Moreover, students are experienced this effectiveness. In this study, we report our findings from our classroom practice.

Class Environment

Matsue is the capital city in Shimane Prefecture in Japan. Shimane is a tranquil prefecture far from major cities. This area is adjacent to Hiroshima Prefecture across the mountains. People in the eastern region including Matsue, tend to be generous, conservative, patient and diligent. On the other hand, people in the western region tend to be cheerful, dynamic, and emotional.

National Institute of Technology, Matsue College called “Matsue Kosen” is a school that mainly aims at growing students up a mid-level engineer. Students interested in engineering and with relatively high academic ability in Shimane Prefecture are admitted. The number of departments is five, which are mechanical engineering, electrical engineering and computer science (DenkiJoho) where the first author belongs, control engineering, information engineering (Joho) and civil environmental engineering. Each department has approximately 40 students per grade level. The school has dormitories. Hence, several students from the western region, other prefectures, or other country are in each class. One class are held in 90 minutes. There are 15 classes per course. In addition to this, one final examination may be given.

Most students in DenkiJoho department enter the program with little experience in computer programming. Some are interested in information technology, but others are not. It is not uncommon for them to have difficulty with programming. Students interested in programming tend to belong to Joho department not this department.

The classes concerned with this study are conducted in the second semester of the third year. DenkiJoho students have experienced a variety of computer-related classes to this point. They learned elementary computer use, touch typing, and Microsoft office software, brief programming using a kit in the first semester of the first year. They wrote HTML, CSS and C programming code in the second semester. This class provides students with the experience of learning by themselves through a step-by-step active learning process (Fujishima, 2019). C language is experienced in three classes. The contents are input/output, variables, conditional branches, and repetitive statements. All codes are given. There are no computer-related classes in the second year. Drawing graphics using Processing in the first semester and microcomputer programming using the C language are taught in the second semester as part of the practical training courses. Starting in the third grade they study the C language for two years. C is the most important programming language in the DenkiJoho department.

During the first semester of the third year, the students learn types, standard input/output, expressions and operators, conditional branches, iterations, and arrays. This subject is taught by a teacher who is not the authors.

Figure 1 is a schematic of the room used for the class. Classrooms are designed for students to work alone. The teacher's computer screen is projected onto a screen at the front of the classroom and onto each sub-display between the students' personal displays.

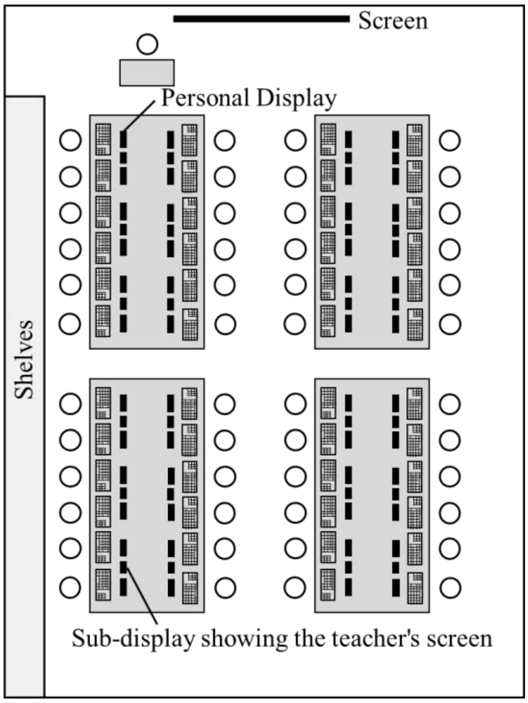


Figure 1. The structure of the teaching room

Teaching Methods

The proposed methodology implements from first to ninth. The 8th class is a mid-term examination. Therefore, the number of teaching classes adopt this study is eight. From the 10th to 15th Python-specific knowledge, scientific library usage, image processing programming and artificial intelligence programming is covered. Table 1 shows what is covered in each class. During the week of the 7th class, functions are treated in C class taught by another teacher, too. In other words, the content of this class catches up with the content of the C language in week 7.

The flow of the class is as follows. First, the teacher (the first author) provides the students with printed materials of the presentation slides. Second, the student logs into the Moodle system and opens the course page for this class. Sample code is placed inside the page. They download them to their computers. Then, the teacher proceeds with the class using presentation slides while students take time to run the sample code. After all explanation are finished, students work on their assignments. These are to rewrite C code into Python code or to write Python code that produces the desired result. They do this by asking questions of us or friends as appropriate. The students are allowed to move seats. In fact, most students do not move due to the structure of the teaching room and other factors.

The process of explanation by presentation slides is as follows. The teacher has the student run the sample code as needed. Sample code is provided through Moodle. First, the teacher explains to the students a relevant unit of the C. The symbol written "C Language" in Japanese in the upper left corner of the slide make it visually clear that this is an explanation of the C. At this time, the teacher explains them in a short time.

Table 1. Theme and Contents

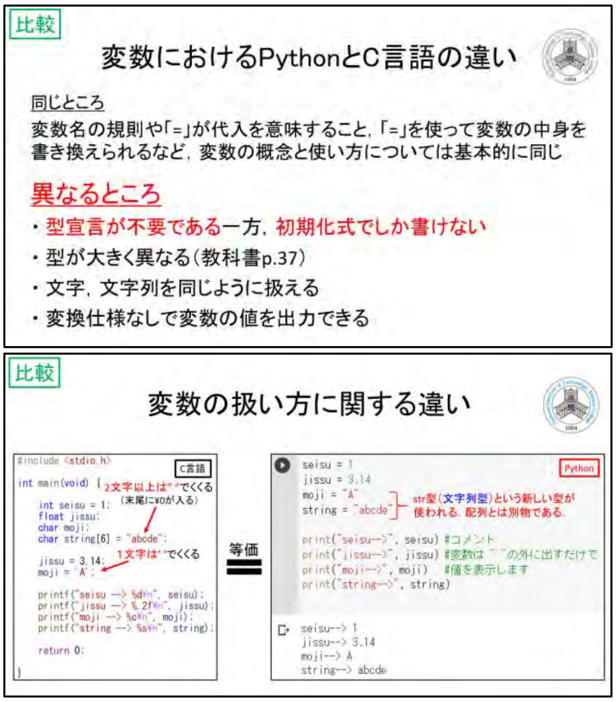
Class number	Theme	Contents
1	Introduction	The term about programming, the kind of translation and the way to use Google Colaboratory.
2	Basic knowledge about the way to use variables	Variable, type, escape sequence, initialization, operator, type conversion, arithmetic, input and output.
3	control statement	Conditional branch, conditional operator and repeat statement using “while”.
4		Repeat statement using “for”, Statements changing the flow of processing (break / contnue).
5	Collection	List type, the way to use “for” statement to list variables, delete / addition, and slice.
6		Tuple/dictionary types, unpack and in/ not in operator.
7	Function (C)	Basic knowledge of functions.
8	Mid-term examination	Translation from C to Python, etc.
9	Function (Python)	The way to write functions, multi returns and default argument.

Next, the teacher teaches knowledge of python in the unit. Basically, he highlights the same and different aspects of python and C using slides with the symbol "Comparison" as Figure 2. Elements that do not exist in the C language are marked with the symbol "Python" to indicate that they are new knowledge as Figure 3.

Both sample codes are executed using web services: coding ground is used for C. Google Colaboratory is used for python. They do not require the configuration of an execution environment. The student copies the text code into the editor section and presses the execute button. The execution result is then displayed.

The Way to Research on Effects

We consider that this method is effective if the students express the following. First, the level of content should feel appropriate or easy. In addition, they perceive the learning rate to be appropriate or slow. In this class, students learn the contents that they spent more than 8 months learning in the C language class in about two months. In other words, the learning progress is very fast.



比較

変数におけるPythonとC言語の違い

同じところ

変数名の規則や「=」が代入を意味すること，「=」を使って変数の中身を書き換えられるなど，変数の概念と使い方については基本的に同じ

異なるところ

- 型宣言が不要である一方，初期化式でしか書けない
- 型が大きく異なる（教科書p.37）
- 文字，文字列を同じように扱える
- 変換仕様なしで変数の値を出力できる

比較

変数の扱い方に関する違い

C言語

```
#include <stdio.h>

int main(void) {

    int seisu = 1;
    float jissu;
    char moji;
    char string[6] = "abcde";

    jissu = 3.14;
    moji = 'A';

    printf("seisu --> %d¥n", seisu);
    printf("jissu --> %.2f¥n", jissu);
    printf("moji --> %c¥n", moji);
    printf("string --> %s¥n", string);

    return 0;

}
```

2文字以上は" "でくくる（末尾に¥0が入る）

1文字は' 'でくくる

等価

Python

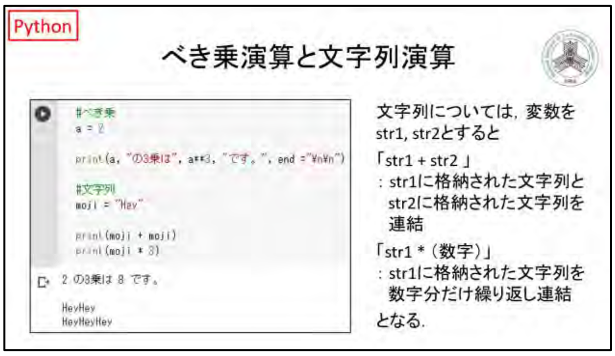
```
seisu = 1
jissu = 3.14
moji = "A"
string = "abcde"

print("seisu-->", seisu) #コメント
print("jissu-->", jissu) #変数は " "の外に出すだけで
print("moji-->", moji)   #値を表示します
print("string-->", string)
```

str型（文字列型）という新しい型が使われる．配列とは別物である．

```
seisu--> 1
jissu--> 3.14
moji--> A
string--> abcde
```

Figure 2. Slides about comparison.



Python

べき乗演算と文字列演算

```
#べき乗
a = 2

print(a, "の3乗は", a**3, "です。", end ="¥n¥n")

#文字列
moji = "Hey"

print(moji + moji)
print(moji * 3)
```

```
2 の3乗は 8 です。

HeyHey
HeyHeyHey
```

文字列については，変数をstr1, str2とすると

「str1 + str2 」
：str1に格納された文字列とstr2に格納された文字列を連結

「str1 *（数字）」
：str1に格納された文字列を数字分だけ繰り返し連結

となる.

Figure 3 A slide with new knowledge about Python.

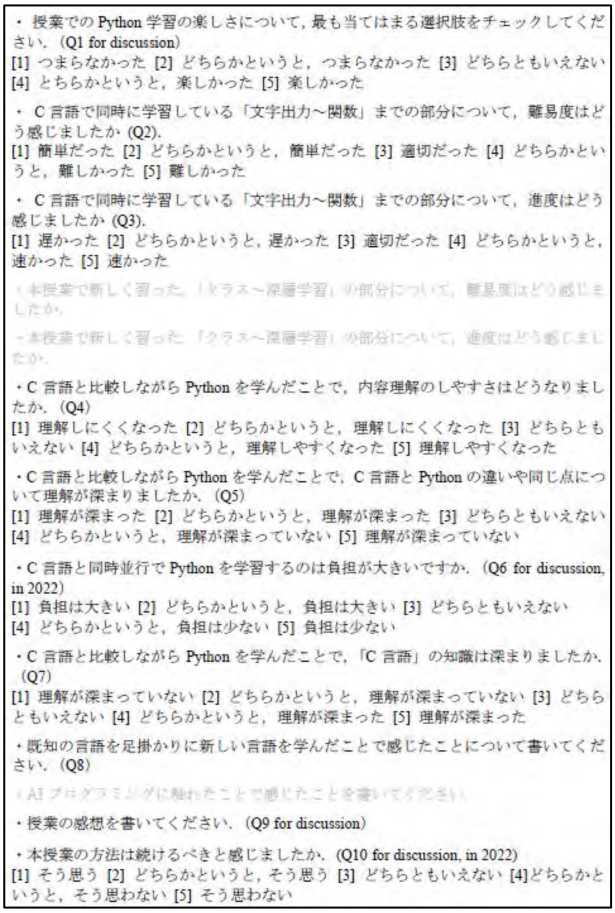
If the students think they can follow along normally or effortlessly, then the effectiveness of this approach is evident.

Second, they feel that the comparison promotes a better understanding of Python. Furthermore, as a secondary effect, we need to research whether they are experiencing a deeper knowledge of the C language. Finally, as aspects other than the effect of the class, it is important to check whether the students enjoyed the class and whether the simultaneous learning was not a burden.

Based on these, the effects have been researched using a questionnaire in the final class in 2021 and 2022 academic year. Questions are written in Japanese shown in Table 2. The teacher told the students that their responses never affect their grades and that they were to respond truthfully.

The questions related to this study are as follows. Where, questions and choices that were difficult to translate into English were converted into words with similar nuances.

Table 2. All questions written in Japanese.



・ 授業での Python 学習の楽しさについて，最も当てはまる選択肢をチェックしてください．（Q1 for discussion）
[1] つまらなかった [2] どちらかというと，つまらなかった [3] どちらともいえない [4] とちらかというと，楽しかった [5] 楽しかった

・ C 言語で同時に学習している「文字出力～関数」までの部分について，難易度はどう感じましたか (Q2).
[1] 簡単だった [2] どちらかというと，簡単だった [3] 適切だった [4] どちらかというと，難しかった [5] 難しかった

・ C 言語で同時に学習している「文字出力～関数」までの部分について，進度はどう感じましたか (Q3).
[1] 遅かった [2] どちらかというと，遅かった [3] 適切だった [4] どちらかというと，速かった [5] 速かった

・本授業で新しく習った「クラス～深層学習」の部分について，難易度はどう感じましたか．

・本授業で新しく習った「クラス～深層学習」の部分について，進度はどう感じましたか．

・C 言語と比較しながら Python を学んだことで，内容理解のしやすさはどうなりましたか．（Q4）
[1] 理解しにくくなった [2] どちらかというと，理解しにくくなった [3] どちらともいえない [4] どちらかというと，理解しやすくなった [5] 理解しやすくなった

・C 言語と比較しながら Python を学んだことで，C 言語と Python の違いや同じ点について理解が深まりましたか．（Q5）
[1] 理解が深まった [2] どちらかというと，理解が深まった [3] どちらともいえない [4] どちらかというと，理解が深まっていない [5] 理解が深まっていない

・C 言語と同時並行で Python を学習するのは負担が大きいですか．（Q6 for discussion, in 2022）
[1] 負担は大きい [2] どちらかというと，負担は大きい [3] どちらともいえない [4] どちらかというと，負担は少ない [5] 負担は少ない

・C 言語と比較しながら Python を学んだことで，「C 言語」の知識は深まりましたか．（Q7）
[1] 理解が深まっていない [2] どちらかというと，理解が深まっていない [3] どちらともいえない [4] どちらかというと，理解が深まった [5] 理解が深まった

・既知の言語を足掛かりに新しい言語を学んだことで感じたことについて書いてください．（Q8）

・AI プログラミングに触れたことで感じたことを書いてください．

・授業の感想を書いてください．（Q9 for discussion）

・本授業の方法は続けるべきと感じましたか．(Q10 for discussion, in 2022)
[1] そう思う [2] どちらかというと，そう思う [3] どちらともいえない [4]どちらかというと，そう思わない [5] そう思わない

Q1. Select the best describes about degree of your enjoyment of learning Python in class.
[1] boring [2] if anything, boring [3] neutral [4] if anything fun [5] fun
Q2. How did you feel about the difficulty level from character output to function which you are learning at the same time by C?
[1] easy [2] if anything, easy [3] appropriate [4] if anything difficult [5] difficult
Q3. How did you feel about the progress speed from character output to function which you are learning at the same time by C?
[1] slow [2] if anything, slow [3] appropriate [4] if anything, fast [5] fast
Q4. What did you find in understanding the content of python by comparing it to C?
[1] hard to understand [2] rather hard to understand [3] neutral [4] rather easy to understand [5] easy to understand
Q5. Did you understand the differences and similarities between them by comparing C and Python?
[1] no [2] if anything, no [3] neutral [4] if anything, yes [5] yes
Q6. Did you feel burden to learn Python concurrently with C? (This question was asked in 2022.)
[1] yes [2] if anything, yes [3] neutral [4] if anything, no [5] no
Q7. Did learning Python by comparing it with the C language deepen your knowledge of the "C"?
[1] yes [2] if anything, yes [3] neutral [4] if anything, no [5] no
Q8. Describe your feelings about learning a new language as a stepping stone to a known language.
Q9. Write your impressions of this class.
Q10. Did you feel that this teaching method should be continued?
[1] yes [2] if anything, yes [3] neutral [4] if anything, no [5] no

Q1 indicates the student's final motivation. Q2 and Q3 do whether the classes are being conducted appropriately within the scope of this study. Q4 and Q5 do whether knowledge was acquired in depth through comparison. Q6 does how the students perceive the burden created by the comparison. Q7 does whether they feel that they have experienced relearning or transfer effects for a known language. Q8 provides a clue as to how learning this method has worked for them. Q9 and indicate their impressions of the class as a whole. Q10 is the students' overall evaluation.

In order to reduce the psychological impact of the order of affirmation and negation on the selection results, the order of the display was intentionally changed in the choice-type questions. Results in the next chapter will present the data in a unified order to improve visibility.

The number of responding students in 2021 is thirty-four; in 2022, it is forty. For questions that used options, the percentage of selection for each item has been calculated.

In the next chapter, the results of Q2 - Q5, Q7, and Q8, which concern only the scope of this study, are discussed first. The discussion will then include Q1, Q9, and Q10, which relate to the overall impression of the class, and Q6 which confirms the burden of parallel learning.

Results and Discussion

The results clearly indicate the effectiveness of this method. We will confirm the items of difficulty and speed, effects by comparison, and transition effects.

Table 3 shows the responses regarding difficulty and speed. more than 80% of the students have found the content appropriate or easy. Moreover, more than 80% have felt that the learning speed was slow or appropriate. In other words, less than 20% answered that it was fast. Therefore, this method adapts the majority of the students to fast learning. Furthermore, they have realized it. Table 4 shows how the comparison affected Python learning. More than 72% students said that the comparison made it easier to understand the content. These results indicate that the transition of learning based on existing knowledge is realized in the class and that the students is able to experience the benefits of this transition. More than 88% of the students have felt that they understood the differences and similarities between C and Python. Fewer than 13% of students find the comparison difficult to understand. Thus, learning by comparison works for many students, and few students have problems.

Table 5 shows the effect of relearning C in comparison. More than 67% students answer that their

Table 3. Evaluation of teaching appropriately

Q2: contents level (%)		
Categorize	2021	2022
Easy	29.4	10.0
If anything, easy	32.4	27.5
Appropriate	32.4	42.5
If anything, difficult	2.94	17.5
Difficult	2.94	2.5

Q3: progress speed (%)		
Categorize	2021	2022
Slow	2.94	2.50
If anything, slow	11.8	12.5
Appropriate	79.4	65.0
If anything, fast	5.88	17.5
Fast	0.00	2.50

Table 4. Effect about understanding by comparison.

Q4: understanding by comparing python to C (%)		
Categorize	2021	2022
Easy to understand	29.4	17.5
Rather easy to understand	47.1	55.0
Neutral	17.6	15.0
Rather hard to understand	5.88	12.5
Hard to understand	0.00	0.00

Q5: Understanding differences and similarities (%)		
Categorize	2021	2022
Yes	23.5	37.5
If anything, yes	64.7	55.0
Neutral	0.00	5.00
If anything, no	11.8	2.50
No	0.00	0.00

Table 5. Relearning or transfer effects.

Q7: experienced relearning or transfer effects (%)		
Categorize	2021	2022
Yes	23.5	15.0
If anything, yes	47.1	52.5
Neutral	17.6	20.0
If anything, no	8.82	7.50
No	2.94	5.00

knowledge of C is deepened. The effect is less effective when compared to understanding Python. However, more than half of the students experienced a further understanding of the language they had already learned through relearning.

Finally, we review the qualitative data obtained in Q8. Table 6 shows the incidence of positive and negative factors in students' descriptions as learning effects. Irrelevant responses found in the responses are ignored. Each is counted if a response contains both positive and negative content. About 3/4 of the responses is positive. 61.0% of the positive comments were related to the expected benefits, such as "I understood it faster," "I understand C better," and "I understand Python better now that I know how it differs from C," and so on. Some comments include, for example, "I was not good at C, but learning Python helped me to deepen my understanding of C. In particular, it was easier to understand the function part through Python." and "I was surprised at the simplicity of Python because I could write many lines of code in Python that I had to write in C.

Table 6. Rate of impressions about comparative learning

Q8: impressions of comparative learning (%)		
Impression	2021	2022
Positive	73.7	77.5
Negative	26.3	22.5

The most frequent negative response was "I was sometimes confused between C and python" which accounted for 9 cases (47.4%) of all negative comments. Three cases said that "the comparison made it difficult."

On the other hand, six of them also noted that the comparison, for example, made it easier to understand. The comments are as follows.

“While there were some similarities, there were also some completely different ways of writing the language, and sometimes it was mixed up with C and sometimes it became a jumble. However, there were many advantages, such as making the C language easier to understand.”

“It was easy to learn because I knew how it worked, but I often got the two languages mixed up.”

“Occasionally, I would confuse C with Python and make mistakes. However, the basic concepts were the same as in C. Therefore, it seemed easier than when I learned programming from scratch.”

“It was easy to understand how the program was executed. However, there were times when I could not tell which was which in the way the code was written in C and Python.”

“I think Python was easy to learn because it has many similarities with C. However, because of this, there were quite a few things that got mixed up and confused in my head. Another factor may have been that I was learning it at the same time as the C language.”

“I feel like it was easier to get into my head than learning all of Python from scratch because of the similarity of the languages. However, it was difficult to learn Python because it seemed to get mixed up with C.”

These results indicate that this method provides significant benefits to students. Moreover, they also explain that the students were able to experience the effects and the difficulties caused by the comparison. The problem is that learning at the same time causes confusion.

From here, we will begin our discussion of this methodology. The topics are as follows.

1. How was the burden on the students?
2. Which scenes can this method be applied?

First, we would like to consider the burden borne by the student. While this method has the advantage of allowing students to reflect on past knowledge, it has the disadvantage of steadily increasing the burden on students. Even if there is a learning effect, it becomes problematic if the burden on students is too large.

Therefore, let us consider the extent to which students consider classes to be a burden.

We have placed a question on the enjoyment of learning Python in Q1, a question asking if there is a burden in Q6, a feedback section in Q9 as a place to express opinions, and an evaluation of teaching methods in general in Q10. Where, the evaluation related solely to the scope of this study is Q6. The other questions include evaluations about classes which are out of study.

Table 7 shows the percentage of responses to Q1 and Q10. Results indicate that many students enjoyed learning Python and think that this style should be continued. These values are influenced by classes out of research target. However, they would not be as high if the students did not also think so within the scope of the study. Thus, it can be evaluated that the students do not evaluate negative about the comparison classes due to burden.

Based on the 2021 results, we surveyed the burden as question in 2022. Table 8 shows the results: 30.0% of students reported some burden, while 42.5% reported little burden. I think the percentage of students who feel burdened is at a level that cannot be ignored. However, we the that the percentage of students who feel less burdened and the aforementioned results taken as a whole do not indicate that this method is unreasonable. This method will be superior if improvements were made to reduce the burden.

Table 7. Evaluation of the enjoyment of learning Python

Q1: enjoyment of learning Python (%)		
Categorize	2021	2022
Fun	38.2	27.5
If anything, fun	50.0	57.5
Neutral	8.82	12.5
If anything, boring	2.94	2.50
Boring	0.00	0.00
Q10: continuation of teaching methods (%)		
Categorize	2021	2022
Yes	-	65.0
If anything, yes	-	30.0
Neutral	-	5.00
If anything, no	-	0.00
No	-	0.00

Figure 8. Burden of comparison work on students.

Q6: existence of burden by comparison (%)		
Categorize	2021	2022
No	-	25.0
If anything, no	-	17.5
Neutral	-	27.5
If anything, yes	-	25.0
Yes	-	5.0

Next, we will consider situations in which this method can be adapted. As mentioned in Q8, a non-negligible number of students reported to confuse the two languages in this method. Therefore, it is necessary to have time to carefully explain the new language and the differences between the two languages. On the other hand, the results of Q2 and Q3 suggest that the speed of instruction could be faster. We think that less confusing units can be taught faster. This method will be applicable if the number of classes is sufficient as a result of considering the balance.

We also think it is important that as many or more similarities between the two languages are exist compared with C and Python. As shown in Q4 and Q7, about 70% of the students felt that the comparison deepened their understanding of the two languages. This number is somewhat low. If many students are unfamiliar with programming, comparison learning may be difficult without many commonalities. On the other hand, several sources, such as Exploring Data (Ramiro, 2019), indicate that the similarity between C and Python is low. Thus, the scope of applicability is not considered narrow.

Finally, this method requires sufficient time in the first year; there are no books that explain the new language by comparing the two languages. Therefore, you must create those texts yourself. One of the determining factors in this method is the availability of time for the teacher in charge.

Conclusions

In this study, we investigated the impact of a class in which students who have already learned C half a year are taught Python in comparison to C. Teachers have students relearn the essentials of C, emphasize the differences between C and Python, and then teach Python code.

The effects by this method have been researched using the questionnaire in the final class in 2021 and 2022 academic year. As a result, the followings is confirmed.

1. this method allows students to experience the benefits of learning from comparison between new programming knowledge and understood one.
2. this allows students to learn new knowledge quickly.
3. many students feel positively about this.

Analysis of qualitative data confirms that the assignment is to reduce language confusion. In addition, about 1/3 of the students feel burdened. This method will be superior if improvements were made to reduce the burden.

We discussed how students feel burdensome and the conditions under which this study can be applied. As a result, we conclude that the burden is not problematic. The applicable conditions may be that there be equal or greater similarity between Python and C, and that sufficient time be allowed for preparation in the first year.

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ENGLISH VOCABULARY LEARNING SOFTWARE DEVELOPED BY STUDENTS AT A NATIONAL INSTITUTE OF TECHNOLOGY (KOSEN)

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Abstract

This article reviews a software development project aimed at assisting EFL learners in analyzing texts and creating personalized word lists. These word lists are stored in a cloud system for later review. The article begins by discussing the pedagogical rationale behind the system, referring to relevant literature and concepts related to second-language vocabulary acquisition. Following that, a demonstration of the software's usage is presented, highlighting its key features. The final section of the article explores various technical aspects of the platform and how they contribute to enhancing vocabulary acquisition. This collaborative project involves instructors and students from a National Institute of Technology (KOSEN), who have contributed their programming expertise and valuable feedback as learners to optimize the software for their own studying needs.

Python is the primary programming language for this project, and uses Python libraries, Django and the Natural Language Toolkit (NLTK). These libraries enable users to perform text analyses and gather information such as word frequency, difficulty, and genre. To provide learners with more specific details about encountered words, the text-analysis tool incorporates data from commonly used word lists as well as custom lists developed within the researchers' institutions. To facilitate efficient review, students can save selected vocabulary in a spaced repetition system (SRS). SRS is a learning tool that presents information at increasing intervals based on the user's performance, ensuring effective long-term retention. It is based on the Leitner System, which organizes flashcards into boxes reviewed at progressively wider intervals to maximize retention. SRS utilizes algorithms to determine the optimal review interval for vocabulary words, promoting efficient retention.

Although similar web-based tools exist, the combination of text analysis functions and SRS makes this software unique, providing learners with a flexible and convenient way to personalize their vocabulary lists. This feature will be particularly beneficial for learners focusing on specialized fields such as engineering. By utilizing domain-specific word lists and vocabulary, students can better prepare themselves to use English in their future professional endeavors.

Keywords: *second language acquisition, data-driven learning, spaced-repetition software, autonomous learning, English for specific purposes*

Introduction

Vocabulary acquisition is foundational in language learning. Wilkins (1972) famously wrote, “While without grammar very little can be conveyed, without vocabulary nothing can be conveyed (p. 111). In regions where incidental vocabulary acquisition is typically unlikely due to limited opportunity to interact in the target language, an intentional vocabulary learning method is very important. Advances in technology have greatly aided this process and in the present, language learners have access to more computer-based vocabulary study tools than one could ever possibly utilize in a lifetime.

The creation of the software presented in this paper was achieved through the collaborative efforts of instructors and students at a National Institute of Technology (KOSEN). It considers various challenges that students may face in language learning, and draws upon on their skills in computer programming to find solutions to these challenges.

A common challenged that Japanese EFL learners face, is the lack of adequate time to review materials as they matriculate up through the education system, leading to gaps in their proficiency. With pressures stemming from entrance exams and standardized tests, there can be a disconnect between the goals and reality. MacWhinnie and Mitchell (2021) contend that the extensive amount of grammar knowledge necessary to score well on university entrance exams leaves limited opportunity to review and engage with materials previously studied. Furthermore, assuming that even when a curriculum is well-connected between various levels, there is a need for students to be able to manage materials previously studied, ideally into one, well-maintained database that is customizable for their aims. The software being developed aims to integrate reading materials, vocabulary lists and corpus software into one, easy-to-use platform that will help Japanese EFL learners improve their learning of vocabulary words.

There are a vast number of computer-assisted language learning mediums to achieve this aim. Currently however, vocabulary acquisition software, extensive reading resources and corpus software exist mainly as separate entities. In Japan, one of the favored methods of vocabulary study is through rote memorization of word lists (Yamamoto, 2014). Reading skills (and to an extent, vocabulary is included in this) are developed in various ways, such as through the use of graded readers, or textbooks, and in recent years, utilizing corpus software. Though students now have access to software made for all three of these areas of study, they could benefit to an even greater extent if these programs were combined into one, integrated platform. This project details the creation of new software that combines aspects of currently available software to provide a practical and efficient learning tool. We will explain how the proposed system has been conceived through research-based reasoning.

Pedagogical Background

Selection of word lists

The selection of vocabulary items for personalized word lists requires careful consideration and informed decision-making based on the learner's needs. For instance, research suggests that focusing on the most frequently used 100 words in English can cover up to 50% of the words found in texts (Nation, 2016). While this information may be well-known to academics, it might be unfamiliar to Japanese EFL learners in tertiary education and below. Therefore, making such information easily accessible to students can help them make better choices for self-study. Word lists, both general and specific, play a crucial role in providing learners with valuable information for selecting words to study. For example, the New General Service List consists of 2,800 vocabulary items, covering 92% of most English-based texts (Browne et al., 2013). Other lists, such as the CEFR-J word list, cater to the specific needs of Japanese EFL textbooks, and the New JACET 8000 categorizes words by difficulty level (Ishikawa, n.d.). These lists, along with others, are included in the software being developed by the authors. A description of the word lists being utilized are described below:

TABLE 1. Selected Wordlists Utilized in the Program (Higa & Ashida, 2023)

Word list	**Type of coverage**	**Reason for selection**	**Number of words**	**Source**
NGSL 1.1	Covers high frequency English words	Covers 92% of the most frequent words in English texts	2800	Browne, C., Culligan, B. & Phillips, J. (2013)
CEFR-J	Corpora of English textbooks used in Japan and neighboring countries	Applies CEFR standards to categorize words by difficulty	7801	Tono, 2022
TOEIC Service	Provides 99% of TOEIC test coverage when combined with NGSL	TOEIC is the most taken test in Japan	1200	Browne, C. and Culligan, B. (2016)
New JACET 8000	Educational word list for Japanese University students	Specifically designed for Japanese EFL learners	8000	Ishikawa, N.D.
Hirotan	Covers basic and advanced words for daily conversation, academics, and business	Word list used in general English classes at Hiroshima University and contains original example sentences	6000	Enokida et al., 2018
MEWL	A word list for medical purposes, it focuses on body systems	Word list used in a medical course at Hiroshima University	1750	Davies et al., 2020

Text-analysis for EFL learners

An additional feature we included in the software was a text-analysis tool to allow learners to perform basic analyses of words they encounter in texts. In our software, this feature allows for students to determine whether or not a word is worth reviewing based on basic data, such as the word lists they are included in, and the difficulty of the word. This is in contrast to the more common method of word memorization in Japan, which is to study word lists aimed at students taking standardized tests. Thomson and Mehring (2016) provided a comprehensive overview of numerous studies supporting the prevalence of rote memorization as the primary vocabulary learning approach among Japanese students. Although this method may prove effective in achieving short-term goals such as passing tests, the lack of contextualization and interaction with words in natural settings makes it difficult to retain these vocabulary items over the long-term. By leveraging simple text-analysis tools, students may enhance their ability to comprehend words at a deeper level, thereby promoting more effective language learning.

Autonomous learning

By equipping learners with the necessary understanding to make well-informed choices regarding word list compilation and basic text analysis, learners will be empowered to engage in self-directed learning beyond formal educational environments. Autonomous learning entails the learner's ability to self-monitor their own learning process and make decisions regarding what they need to learn, how to learn it, and how to apply it. According to Schwienhorst (2007), learner autonomy is characterized as "a learner-centered approach to learning, encouraging learners to critically reflect on their learning process and establish a personally meaningful connection with it" (p. 11). This approach proves particularly advantageous in second language acquisition as it allows learners to customize their learning experience according to their unique needs, interests, and relevant areas of focus. Furthermore, it addresses the issue of maintaining continuity throughout different stages of study.

Retaining knowledge and educational materials from an institution for self-study purposes after leaving formal education presents a challenge in language learning. This challenge becomes especially pertinent when English proficiency is required outside of an academic setting. The research and development of engineering English materials conducted by the first author have highlighted the absence of an organized methodology among professionals to apply the knowledge acquired during their tertiary education to their respective fields. One objective of this software is to bridge this gap by enabling users to store and access study materials and data for future review and study.

Data-driven learning (DDL)

Data-driven learning (DDL) is an approach that utilizes data to inform and guide the learning process, empowering individuals to gather data and make informed decisions about their own study path. Szudarski (2017) emphasizes that DDL not only raises learners' awareness of real-life language usage but also fosters autonomy by encouraging them to take responsibility for their learning process. Furthermore, our software's DDL approach facilitates a shift from passive to active learning as it encourages learners to actively engage with texts and think critically while reading.

Additionally, while general word lists are essential for foundational learning, some students may have specific goals, such as their future profession or a particular academic context, for learning English. Access to text analysis tools allows learners to make informed choices about what to study based on their individual needs. Anthony (2018) suggests that while general word lists provide valuable information, learners can acquire more specific knowledge by conducting their own text analysis. Browne et al. (2013) support this idea, advising learners that studying vocabulary beyond the NGSL 1.1 list is best achieved by focusing on words within their specialization. They state, "The number of words they need to learn to make an additional 1% coverage gain increases sharply after 92%, and… depending on the student's specialization, it is very likely that they will make significantly faster gains by learning special purpose vocabulary" (n.d.). This viewpoint highlights the importance of tailoring vocabulary studies to specific needs and interests. Our aim is to facilitate this process by enabling users to compile personalized word lists.

Software Development

The software developed in this project has been provisionally called the "Hi-lex System" (short for *Hiroshima-lexicon system*). It is composed of two primary elements: a user interface (frontend), which encompasses the visible aspects on the website, and a server-side component (backend), responsible for handling user accounts, storing word lists, and generating data accessible to researchers and site administrators. Here's an overview of the functions users have access to:

TABLE 2. Main Functions of software

Users of this software will be able to:
1. choose texts (autonomous learning)
2. perform vocabulary profiling analysis based on selected word lists (Data-driven learning)
3. compile and save personalized word lists (autonomous learning)
4. review words efficiently (Spaced repetition)
5. store reading materials for future review

A visual for the process of how the software is used can be found below:

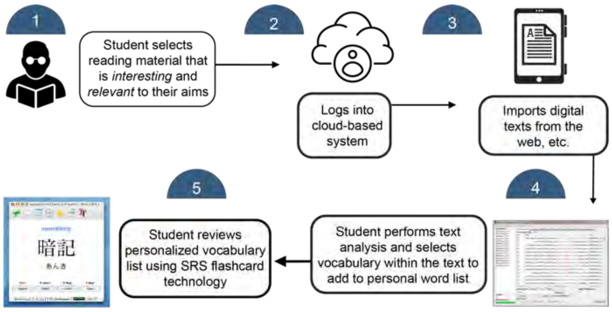


FIGURE 1. Visualization of the Vocabulary Selection Process (Higa & Ashida, 2023)

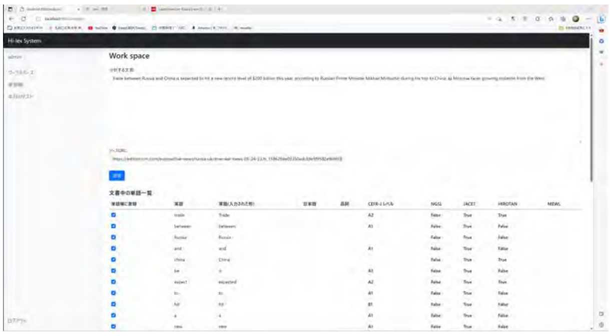
The software takes advantage of the open-source data analysis library in Python, called the Natural Language Toolkit (NLTK), designed to process human language data. It was created in the late 1990s by Steven Bird and Edward Loper at the University of Pennsylvania to aid in natural language processing (NLP)and is able to perform lexical tasks such as tokenization, part-of-speech tagging, parsing, semantic reasoning, and sentiment analysis. NLTK provides developers with to access to vast linguistic datasets. It is distributed under the Apache 2.0 open-source license, which allows users to freely use, modify, and distribute the NLTK codebase.

The front end of the application was developed with another Python library, Django, a Python web framework that provides a set of libraries for web development. Django includes features such as form handling, user authentication, and an administration interface, which are utilized in our application. With Django, developers can build dynamic and scalable web applications quickly, thanks to its comprehensive set of built-in functionalities.

The design was achieved by using Bootstrap, a front-end framework that provides a collection of pre-designed CSS and JavaScript components. It aids in the development of responsive web interfaces by offering a grid system, typography, navigation bars, buttons, forms, and other user interface (UI) elements that can be integrated into web projects.

In order to review vocabulary items chosen by the student, a spaced-repetition system (SRS) is used. SRS is a learning technique that optimizes review schedules by spacing out the intervals between learning sessions based on the difficulty and retention of the material, enhancing long-term memory retention. The SRS component of the software utilizes the SuperMemo2 algorithm, developed by Piotr Wozniak, a Polish computer scientist and founder of the SuperMemo World company. SuperMemo2 calculates an optimal review interval for each item based on the user's historical performance in recalling that item. When an item is correctly recalled, the interval until the next review is extended, allowing for longer gaps between reviews. Conversely, if an item is forgotten, the interval is shortened, leading to more frequent reviews. This adaptive algorithm aims to strike a balance between challenging the learner with timely reviews and avoiding overwhelming them with excessive repetitions. By systematically adjusting the review intervals, SuperMemo2 maximizes memory retention and helps learners efficiently retain information over the long term.

At the present, the front end of the software can be seen in the screenshot below:



Hi-lex System

Work space

文書中の単語一覧

FIGURE 2. Screenshot of Hi-lex System

Discussion

Talk about using SuperMemo 2 and how it could be edited later on depending on feedback about the algorithm. At the time of this writing, the authors have not yet conducted a study on the effectiveness of the software, nor have they received formal feedback from users. This will

At the time of this writing, the software is hosted locally, and not available on the internet. However, upon completion of the software, it will be deployed on a cloud system to enable users to use the software on multiple devices.

Conclusion

This paper has surveyed some of the innovations in language learning tools related to second language vocabulary acquisition and selected various elements of this software that can serve the constituents the authors are most familiar with, in this case, Japanese students studying engineering. We have reviewed some of the current online corpus and vocabulary acquisition tools available for self-study and hope to add to this current body of software based on the specific needs of the students we are familiar with. As practitioners and learners, we hope that the software being developed in this project will enable students to take more agency in the selection and compilation of their word lists, engage with texts more actively, and make their studying more efficient.

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A SELF-LEARNING SUPPORT SYSTEM BASED ON AN EYE-TRACKING ANALYSIS OF A DUAL TASK IN ENGLISH: PILOT STUDY (2)
SUPPORTING A STUDENT WITH DYSLEXIA

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Abstract

This is the second pilot study to create a self-learning support system based on an eye-tracking analysis of a dual task in English as a foreign language. In the previous study, four students were recruited as subjects with their agreement to use their experimental data for this research. Two subjects had scored above 500 on the TOEIC®test and the other two less than 300. Each subject participated in the experiment by solving the same question of TOEIC Listening Part 3 on a computer screen, and their eye-movements were recorded. Then, visualizing their eye-movements while listening to and reading English at the same time on the TOEIC®test, the students with lower TOEIC scores observed the patterns of their own irregular eye movements that seemed to indicate confusion, such as wandering or staying put while listening to and reading the text. Through the observation, they recognized the incomprehensible words or phrases that inhibit comprehension. In this second pilot study, one student with dyslexia was recruited as a subject who had a low TOEIC®test score after consenting to his data being used for research. The purpose of this pilot study was to examine the subject's eye-movement data and determine the self-learning aspects by helping him trace his eye movements, examining his confusion, and enhancing his meta-cognition through the comparison of his data with a subject who had scored above 500 on the TOEIC®test. The subject participated in the experiment twice, once by solving the questions of the TOEIC Listening Part 3 and then, by doing "*kikiyomi*", which is known as listening while reading a text, on a computer screen on a different day. His eye-movements were recorded at both times. Then, visualizing the student's eye movements, he observed the patterns of his own irregular eye movements that seem to indicate confusion, such as wandering and going backward while doing "*kikiyomi*" the text. Through the observation, he recognized his attitude that inhibits English listening comprehension.

Keywords: *eye-tracking, kikiyomi, visualization, fixation, saccade*

Introduction

This is a pilot study of a self-learning support system based on an eye-tracking analysis of a dual task in English. The final aim of this research is to help students overcome any difficulty in not only solving TOEIC listening questions but also explaining their confusion with words. By visualizing an individual student's eye movements while listening to and reading English at the same time on the TOEIC®test, students can observe the patterns of their own irregular eye movements that seem to indicate confusion, such as wandering, or staying put while listening and reading the text. Through this observation, they should recognize the incomprehensible words or phrases that inhibit comprehension. The eye-tracking analysis also raises the teacher's awareness of the specific elements that prevent students' comprehension during the dual task. Through the student-teacher interaction focusing on eye-tracking during the dual task as well as reading aloud practice, each student is encouraged to develop strategies for a better comprehension, so that they can continue to improve their learning attitude autonomously. Through conducting this meta-cognitive learning experiment and examining its validity, this research leads to establishing a unique self-learning support system fostering students' autonomous learning attitude.

As a background of this research, NIT, Hakodate College started teaching its mandatory TOEIC e-learning course to all fourth-year Japanese students in 2018 (Okuzaki, Hirano, and Maruyama, 2020). All fourth-year Japanese students must acquire 330 or above in the first quarter and 350 or above in the second quarter of their fourth-year by taking a computer-based mock TOEIC examination to obtain the credits required for graduation.

In pilot study (1) (Okuzaki and Moriya, 2023), which entailed visualizing their eye movements while listening to and reading English on the TOEIC®test, the students with lower TOEIC scores observed the patterns of their own irregular eye movements that seemed to indicate confusion, such as wandering or staying put while listening and reading the text. Through this observation, they recognized the incomprehensible words or phrases that inhibit comprehension.

In this pilot study (2), one student with dyslexia was recruited as a subject with a low TOEIC®test score after consenting to their data being used for research. According to International Dyslexia Association, dyslexia is a specific learning disability that is neurobiological in origin, and it is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the formation of vocabulary and background knowledge (https://dyslexiaida.org/definition-consensus-project/). The student had been reasonably accommodated since his first year in NIT, Hakodate College, and cooperated with this research to understand his disability.

The subject participated in this experiment based on his personal schedule. Before the experiment, he was briefed about the experiment by the teacher, and after obtaining his consensus, the experiment was conducted.

Purpose

This pilot study aimed to examine the subject's eye-movement data and determine the self-learning aspects by helping him trace his eye movements, examining his confusion, and enhancing his meta-cognition through the comparison of his data with those of a subject who had scored above 500 on the TOEIC®test.

The Environment and Procedure of the Experiment

The experiment was conducted with Tobii Pro Nano produced by Tobii. under the same conditions as the pilot study (1). Tobii Pro Nano (Figure 1) is a screen-based eye tracker that captures gaze data at 60 Hz and is designed for fixation-based studies. This easy-to-use, robust research system is an ideal entry point for those considering beginning eye-tracking research or those wishing to take their eye-tracking research out of the lab environment (https://www.tobii.com/ja/products/eye-trackers/screen-based/tobii-pro-nano). This tool was used mounting on a Toshiba Dynabook equipped with Intel Core i7 (Figure 2). The experimental device was set on a table in front of Okuzaki's laboratory screened off from a corridor (Figure 3). Each experiment was recorded using two video cameras with different angles.

Figure 1. Tobii Pro Nano

Figure 2. Tobii Pro Nano mounted on the computer

Figure 3. Experimental environment

Figure 4. Answering tags for the experiment

Once the teacher said "HAI," a subject pushed the computer's enter key to switch the scene on the screen. By observing the statements and choices on the screen, the teacher played a CD for a listening question. In this experiment, the questions examined were obtained from the Listening Part 3 from 68 to 70 in the new official workbook of TOEIC®test (2005). In the TOEIC®test, one answer should be chosen from four choices and then marked on an answer sheet. However, in this experiment, a subject was required to pick up a card from A, B, C, and D in front of the computer (Figure 4) and show it to the camera while listening to the question statement, four choices, and then a pause before the next question statement.

The location and angle of the computer screen, as well as the subject's chair, were controlled to conduct the experiment with all the subjects under the same condition. Figure 5 shows how the subject's eyes were detected by Tobii Pro Nano. The center of the computer screen illustrates how Tobii Nano Pro reflects the subject's eye sight on the screen. The two white dots represent the subject's eyes, and as long as they stay inside the inner square marked by the yellow lines, the experimental data are valid. Each subject was required to maintain their eye positioning and sitting posture before the experiment started.

Figure 5. Detecting a subject's eyes on the computer

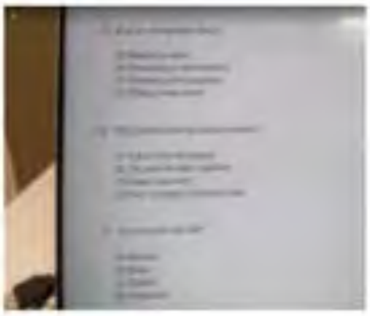


Figure 6. Listening statements and choices of questions 68 to 70 on computer screen

Experimental Process

In this study, two experiments dealing with a dual task in English were conducted with the subject. The first experiment was the same as the one held in the pilot study (1): answering questions 68 to 70 of TOEIC®test Listening Part 3 for about 100 seconds. Question statements and choices were displayed on the computer screen (Figure 6).

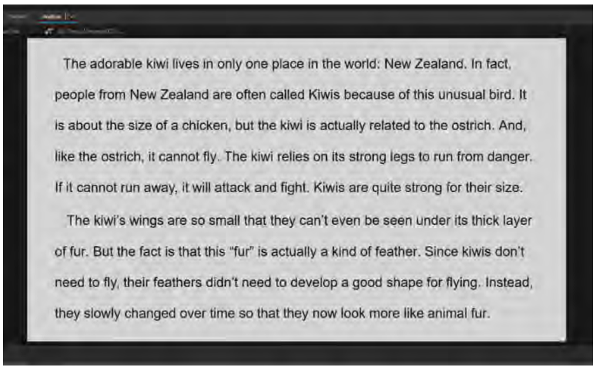
The recording of the listening questions was edited by the researcher, and the subject started listening to the explanation of Part 3 before the actual conversation and question statements. The following is the transcript of the actual listening CD used for this experiment. Each squared number indicates how much time has passed in blocks of 10 seconds.

You will hear some conversations between two people. You will be asked to answer three questions about what the speakers say in each conversation$\boxed{10}$*. Select the best response to each question and mark the letter A, B, C, or D on your answer sheet*$\boxed{20}$*. Conversations are spoken only one time and will not be printed in your test book.*
Questions$\boxed{30}$ *68 to 70 refer to the following conversation.*

(Woman) Have you finished putting together that advertisement yet? We really need to run it$\boxed{40}$ *in the next couple of days.*
(Man) I've just got a couple of questions for you about it. I listed two job openings for reporters. Is there anything else?
(Woman) We$\boxed{50}$ *need to advertise for another assistant, too —for clerical support. We haven't had enough help lately.*
(Man) And the reporters need to send us writing samples, right?$\boxed{60}$ *You know, given the current job market, I'm very optimistic about who we'll get.*

No.68 What are the speakers$\boxed{70}$ *doing?*
(pause)
No.69$\boxed{80}$ *What problem does the woman mention?*
(pause)$\boxed{90}$
No.70 How does the man feel?
(pause)$\boxed{100}$
Go on to the next page.

The second experiment was to examine how the subject reads a text on the screen following the English to which he listens. According to Gerbier, Bailly, and Bosse (2018), this action is described as reading while listening to texts (RWL), which is a promising way to improve the learning benefits provided by a reading experience. Kadota and Noro (2010) describe this action as "*kikiyomi*" in Japanese. The experiment was thus conducted using the text and the model English recording that the subject had learned in the second fiscal year of NIT, Hakodate College. Figure 7 shows the actual display used in this experiment.



The adorable kiwi lives in only one place in the world: New Zealand. In fact, people from New Zealand are often called Kiwis because of this unusual bird. It is about the size of a chicken, but the kiwi is actually related to the ostrich. And, like the ostrich, it cannot fly. The kiwi relies on its strong legs to run from danger. If it cannot run away, it will attack and fight. Kiwis are quite strong for their size.

The kiwi's wings are so small that they can't even be seen under its thick layer of fur. But the fact is that this "fur" is actually a kind of feather. Since kiwis don't need to fly, their feathers didn't need to develop a good shape for flying. Instead, they slowly changed over time so that they now look more like animal fur.

Figure 7. The text for "*kikiyomi*" on a computer display

The subjects' TOEIC®test data

This study's subject is indicated as Subject ① to compare the data with Subject ②, who participated in the the same experiment in the previous study (Okuzaki and Moriya, 2023). Table 1 shows each subject's total TOEIC®test scores. At the time of the experiment, Subject ① was a third-year student and Subject ②was a fourth-year student of NIT, Hakodate College.

Table 1. Subjects' TOEIC®test data

Subject	Experi-mental date	TOEIC total score	Listening score/ Reading score	TOEIC test date
①	12.13.2022	170	85/85	09.30. 2020.
②	12.21.2021	510	295/215	04.10. 2021.

Results of and Considerations on the First Experiment

Figure 8 shows the comparison of each subject's heat map. The data were acquired for 80 seconds while the subjects were taking the TOEIC listening test.

The heat map visualizes how much attention a subject pays to the screen while answering the listening test by color temperature (Tobii Pro AB, 2022). The more focused and gazed area is indicated as red and the less focused and gazed one as green. The heat map comparison indicates that Subject ② has more high-color temperature areas than Subject ①. Furthermore, based on the portions of the colored area, Subject ① seemed to pay less and less attention to the middle and lower parts of the screen while Subject ② seemed to pay attention to the upper, middle, and lower parts of it.

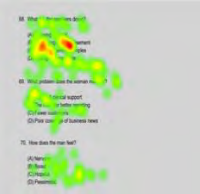
Subject	①	②
Heat map		

Figure 8. Heat maps of two subjects for 80 seconds during the TOEIC listening test

Fugures 9 and 10 show the gazing plots of subject ① and subject ②, respectively of the first 80 seconds during the TOEIC listening test. The gaze plot illustrates how long the gazing time is by the size of a circle (Tobii Pro AB, 2022), and the movement direction and distance are shown by the line between each circle (Tobii Pro AB, 2022). Each gazing plot has a number to indicate the plot's order in the total gazing actions. The last gazing plot number is recognized as the total gazing number.

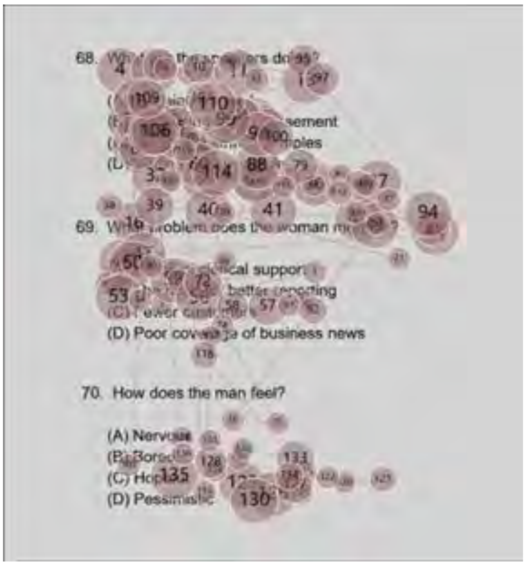


Figure 9. The enlarged view of Subject ①'s gazing plot

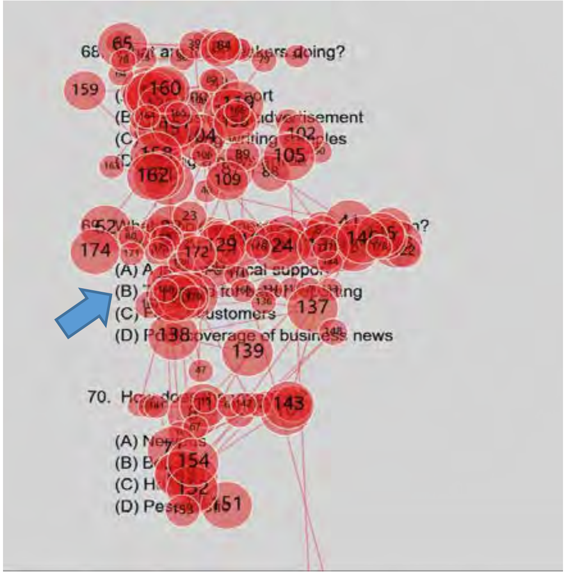


Figure 10. The enlarged view of Subject ②'s gazing plot

Underwood and Batt (1996) state that when reading English, a reader fixes their eyes from left to right repeating a small saccade, and at the right edge, their eye conducts a return sweep. However, when reading a difficult paragraph, some readers return their eyes to the place they once read, which is explained as a regression phenomenon. By checking the number on each gazing plot in Figure 9, it is considered that more regressions occurred when Subject ① was reading the text of the TOEIC listening test on the screen than when Subject ② was doing the same shown in Figure 10.

Figure 9 shows that the total gaze plots of Subject① are 135 (explicated by the blue arrow on Figure 9). By observing the gazing plots in Figure 9, it is clear that the subject's eyes were moving roughly and repeatedly up and down in a wide range with longer saccades and skipping questions 69 and 70. Therefore, it is assumed that Subject ① might have guessed the answers of 69 and 70 without activating written and aural information.

On the other hand, the total gazing plot number of Subject ② are 180 (explicated by the arrow in Figure 10), which means that Subject ② gazed to the screen 45 times more than Subject ①. The plots of Subject ② are rather connected with shorter saccades, which means the eyes are moving faster from left to right with a shorter fixation time. Furthermore, the gaze plots are more focused on written information with less gaps. It is assumed that Subject ② guessed the answers depending on written information.

Results of and Considerations on the Second Experiment

The second "*kikiyomi*" experiment was conducted to be done just once 1 week after the first experiment only with Subject ①. Figure 11 shows the gazing plots of the second experiment the first time.

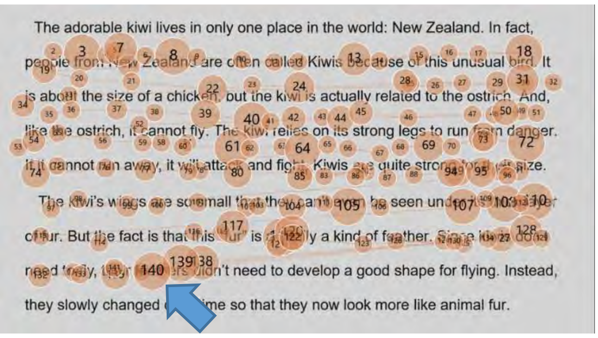


Figure 11. First gazing plots of Subject ① during "*kikiyomi*" experiment

At the second last line of the paragraph, the regression occurred, and Subject ① could not follow the text along with its narration. Then, Subject ① requested the second trial of the same "*kikiyomi*" experiment. Figure 12 shows the gazing plots of the second experiment the second time.

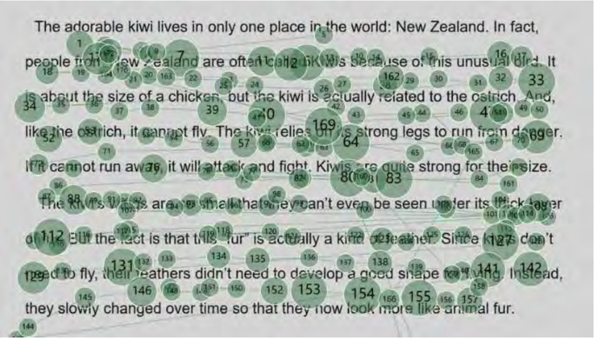


Figure 12. Second gazing plots of Subject ① at "*kikiyomi*" experiment

At the end of the first "*kikiyomi*" experiment, the examiner asked Subject ① for feedback of on it, and Subject ① answered that he had found himself lost in the second last line of the paragraph. He could not verbalize the reason immediately; however, he seemed to have confused *feathers* in the line as *feather* in the third last line and had regressed from the second last line to the upper line to look for the word *feather* while listening to the narration. In the second "*kikiyomi*" experiment, he had not fixated on *feathers* and had finished reading at the speed of the narration. After these experiments, Subject ① was able to read the whole text and pronounce *feather* with the correct Japanese meaning.

Student's self-awareness focusing on eye-movements in the experiments

Four weeks (including winter vacation) after the two experiments, Subject ① reviewed the experimental data regarding his eye-movements in the dual task in English with the examiner and admitted that they show three features: (1) bias of gazing location, (2) answers given without written information, and (3) regressions occurring during listening comprehension. Consequently, Subject ① proclaimed that when he performs a dual task in English, he patiently keeps moving the eyes from left to right toward the bottom even though he gets confused. He realized that when he is lost in the meaning and does regressoins on the text, he misses new information to be acquired through listening comprehension.

One month later, he scored 350 (Listening score: 255; Reading score: 95) on the TOEIC mock test and obtained the credit of Practical English1A required for graduation from NIT, Hakodate College.

Coclusion

The subject participated in the experiment twice, once by solving the questions of TOEIC Listening Part 3 and next, by doing "*kikiyomi*" on a computer screen on a different day. His eye-movements were recorded both times. Then, visualizing his eye-movements, he observed the patterns of his own irregular eye-movements that seemed to indicate confusion, such as wandering and going backward while listening to and reading the text. By observing his eye-movements, he recognized his attitude that inhibits English listening comprehension, and consequently, he achieved the minimum total score on the TOEIC mock test required for graduation from NIT, Hakodate College.

According to Koike et al. (2008), listening skills do not only play the most fundamental role by allowing a listener to comprehend and correctly respond to what a speaker says, but they also help the listener acquire, control, and improve speaking, writing, and reading skills. They also claim that listening skills are highly transferred to other skills in English learning. If this experimental support worked to improve Subject ①'s listening skill, the reading score would have increased as well; however, it did not. Therefore, it cannot be argued that this experimental support directly worked to improve the subject's listening and reading skills for the TOEIC®test.

Next Steps

According to Kadota (2012), a student who studies English as a second language must make a phonological code by reading written input, similar to a phonological code formed by listening to vocal input. Then, he suggests that shadowing and reading aloud practice is effective as training for forming phonological codes autonomously. On the other hand, O'ki and Izumi (2015) suggest that accelerated speech dictation is more learner-friendly than shadowing. The study's next step is to find out a better self-training practice combining shadowning and reading aloud practice with accelerated speech dictation through examining how subjects eye-movements change after training.

The final goal of this research is to establish a unique self-learning support system fostering students' autonomous learning attitude through conducting this meta-cognitive learning experiment and examining its validity. According to Strohmaier, MacKay, Obersteiner, and Reiss (2020), in mathematics education research, eye tracking seemed particularly beneficial for studying processes rather than outcomes, for revealing mental representations, and for assessing subconscious aspects of mathematical thinking. Focusing on eye-tracking analysis of dual tasks on TOEIC®test, it is expected to develop self-learning strategies for students to acquire a better comprehension skills, so that they can continue to improve their learning attitude autonomously.

Acknowledgements

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Additional Statement

We publish this research with the approval of the student's parent. This research has also been approved as making adequate provisions for the safety and privacy of subjects by the Life Ethics Committee of Hakodate National College of Technology.

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LEARNING INVIGORATED: USING MICROLEARNING AS A TEACHING METHODOLOGY

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Abstract

Republic Polytechnic (RP) adopts a learner-centred approach, acknowledging student voice as central to the learning experience by employing instructional strategies, such as problem-based learning, project-based learning, interactive seminars and cognitive apprenticeship. With technology revamping the way humans live, communicate and conduct business, e-learning is increasingly used as a mode of lesson delivery in the campus. Together with the other learner-centred instructional strategies, Microlearning (ML) which is an instructional design that delivers information in a smaller and easier-to-digest format, has the potential to be weaved into the curriculum to achieve the desired learning outcomes.

In this study, a conceptual framework is developed to implement microlearning in the curriculum at Republic Polytechnic for learner-centred environment. The framework covers:

- **What is microlearning?**
- **Why should microlearning be implemented in the curriculum?**
- **What are the key features of microlearning?**
- **How to implement microlearning?**

This study assesses the effectiveness of the proposed framework for microlearning implementation in RP aligned to the institution's needs. It looks at how microlearning can be used to deliver content and complement traditional teaching and learning, reinvigorating students' love for learning.

Four SCORM packages were implemented in a lesson to gain useful insights into the learner's reaction and learning through microlearning. The results, derived from Focus group discussions (FGDs), indicated that the learners considered short duration of the microlearning courses helped enhance comprehension, enabled accessibility and increased interactivity.

Keywords: *e-learning, microlearning, bite-sized learning, anytime, anywhere, learner-centred.*

Introduction

Microlearning, as its name suggests, is most often referred to as bite-sized learning or training. However, there are many definitions of microlearning and in reality, it goes beyond just delivering information in a shorter duration. It is increasingly perceived as a modern trend in learning that allows learners to learn anytime, anywhere. It has also evolved as an instructional design to support learning in the VUCA (volatility, uncertainty, complexity, and ambiguity) world whereby average attention span of people has decreased over the years, and the dynamics of constant information overload makes it difficult for them to absorb and retain the knowledge (Bastow, 2022).

Despite the fact that microlearning is yet to be described in detail (in research studies, methodologies and textbooks), it is increasingly used as a means of teaching due to its unique cutting-edge approach in benefiting learners of all ages. There are diverse explanations to prove why microlearning works, such as processing bite-sized bits of the content may increase information retention by 20% (Giurgiu, 2017), as it reduces cognitive load (Hogle, n.d.). In most cases, microlearning delivery leverages on technology and is made available on any smartphone, tablet, or portable computing device. This brings benefit in the aspect of accessibility. On top of that, microlearning has been found to increase learners' conceptual understanding and act as a stimulus for intrapersonal growth. It also boosts learner's self-expression and provides more meaningful opportunities for social interaction among learners (Brebera, 2017).

In order to use microlearning instructional design, educators will need to comprehend what is microlearning, the purpose of using microlearning, the key elements that constitute microlearning and how microlearning can be designed and weaved into the curriculum to meet its intended purpose. The development of the microlearning conceptual framework incorporates the above-listed attributes and aims to help educators identify and deliver suitable learning content using microlearning. In addition, the implementation of microlearning will enhance the learning experience of the learners.

In this study, a common issue among learners was identified: difficulty in retaining information. Existing literature in the field of microlearning was studied to assess its use to develop a conceptual framework for RP.

The framework was then outlined in a guide as a means to provide an overview of microlearning as well as how to design a microlearning lesson in RP's context to all teaching staff.

To evaluate the effectiveness of the framework, a lesson design for the module on critical thinking and problem-solving skills, which comprises four microlearning courses for preliminary data collection, was implemented. Qualitative feedback data was collected from learners to address the following research question (RQ)s:

RQ 1: Does the microlearning framework aid learners' learning?

RQ 2: How do learners perceive their learning using microlearning courses?

Basis of Microlearning

Hermann Ebbinghaus, a German psychologist, noted that memory does not stay consistent. Depending on the subject matter and the methods of learning, memory power can increase, decrease, increase, decrease, in an ongoing cycle. As depicted in the Forgetting Curve (Figure 1) which he discovered in 1885, **80% of the knowledge** learnt is lost within one month.

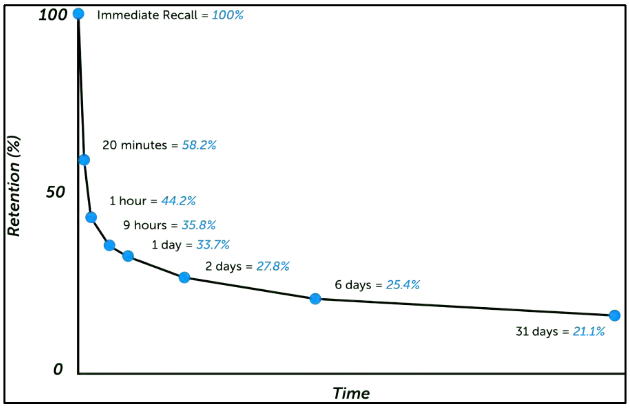

Figure 1: Ebbinghaus Forgetting Curve graph

At the same time, Ebbinghaus also discovered the method of **Savings** which refers to knowledge once held at the top of the mind, in its entirety or near to complete accuracy, as well as the retention of the information thereafter. Frequently revisited information can be recalled much easier even after a significant time of not using it.

When learning large amount of information all at once, it is virtually impossible for learners to retain all information. Certain information will be retained in learners' short-term memory but the knowledge will degrade over time if not repeated and reinforced.

The microlearning concept of splitting the content into bite-sized pieces and recalling different parts of it throughout a spaced interval can help improve knowledge retention and productivity.

In the Ebbinghaus' memory retention graph (Figure 2), it can be seen that when one learns something new, all the information will be retained. However, as time goes by, memory retention starts to drop. But then again, if the information is continuously reviewed, the retention of it increases.

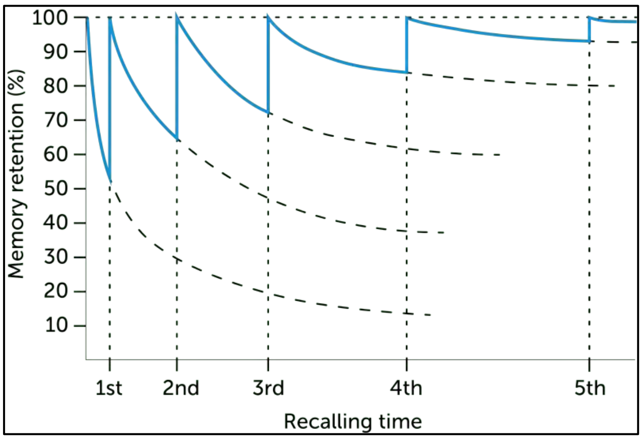

Figure 2: Ebbinghaus Memory Retention graph

However, these are some ways to beat the forgetting curve and ensure that knowledge is retained (JoyForm by JoyfulPerson, 2022):

- **Spaced learning.** According to Ebbinghaus, knowledge can be easily retained if divided into chunks and repeated over measured intervals.
- **Just-in-time learning.** For important tasks or tasks that are not performed frequently, provide learners support at their point of need with microlearning, helping learners put the knowledge acquired into practice.
- **Micro assessments.** Encourage learners to review and test their acquired knowledge at regular intervals so that the information is embedded into their memory.

This paper seeks to develop a framework to look at how information can be shared and received, amid the shrinking human attention span. Despite being constantly flooded with information, it cannot be denied that people now have the ability and luxury to be highly selective about the information consumed and absorbed. Thus, it is more than ever crucial to change the way information is delivered (to capture people's attention) (JoyForm by JoyfulPerson, 2022b).

Why Microlearning?

There are various key factors attributing to why microlearning courses are more efficient than traditional ones with longer duration, as depicted in the following (Qualee Technology, 2022):

- **Fast impact.** Learners tend to understand a topic faster when presented with concise and focused information. In addition, microlearning lowers the threshold to start a new topic.
- **Increased freedom.** As microlearning lessons are usually presented on an accessible digital platform with manageable chunks of information, learners can learn at their own pace and convenience.
- **Elevated engaging experience.** Learners perceive microlearning to be engaging. The experience for learners is similar to browsing their favourite social

media app, as opposed to the "serious study" feel of a regular classroom setting.

- **Improved knowledge retention.** When a subject is studied repeatedly and can be easily revisited, knowledge retention is higher. When information is concise, it also prevents cognitive overload.

By applying this to RP’s context, microlearning is a teaching and learning method that:

- serves to bridge a just-in-time knowledge or skill-based gap
- is accessible through a digital platform that allows learners to learn anytime, anywhere
- consists of self-contained, bite-sized learning activities that last no more than 15 minutes

Proposed Conceptual Framework for Microlearning

The proposed conceptual framework for microlearning comprises the elements depicted in Figure 3.

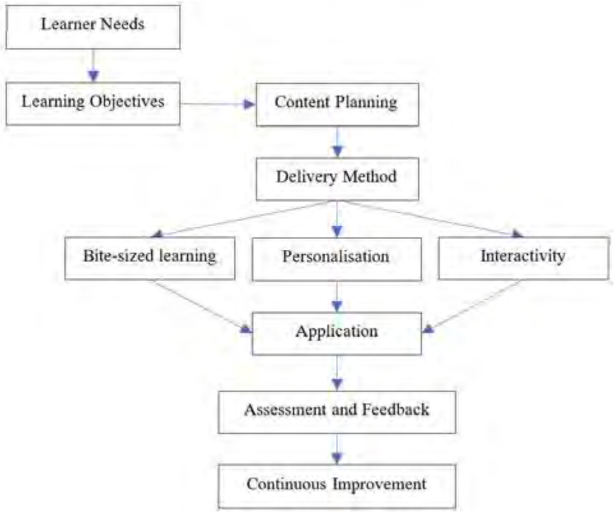

Figure 3: Conceptual Framework for Microlearning

- **Learner Needs.** Learners’ needs and preferences guide the design of microlearning courses. Understanding learner's goals, interests, and prior knowledge is important for creating effective microlearning content.
- **Learning Objectives.** The specific knowledge and skills that learners are expected to acquire through the microlearning experience should be measurable and aligned with the lesson’s overall learning objectives.
- **Content Planning.** Consists of ***content strategy*** that defines the topics and skills that will be covered in the microlearning course, as well as ***content design***, which is the process of creating and organising the actual content.
- **Delivery Method.** Microlearning courses can be delivered through a variety of methods, such as video, audio, text, or interactive simulations. The delivery method should be selected based on the learner's needs and the content planning.
- **Bite-sized Learning.** Microlearning course is delivered in bite-sized units that can be easily consumed in less than 15 minutes. Each course focuses on a single concept or skill and is designed to promote deep understanding and retention.
- **Personalisation.** The microlearning content should be tailored to meet the learner's needs and preferences, such as being able to learn anytime, anywhere.
- **Interactivity.** The microlearning course should be designed to encourage active participation and engagement, such as through quizzes, games, social media or other interactive activities.
- **Assessment and Feedback.** Assessment and feedback help to ensure that learners acquire the desired knowledge and skills. Assessments should be aligned with the learning objectives and provide learners with meaningful feedback on their progress.
- **Application.** Microlearning courses should be designed to allow learners to apply their new knowledge and skills in real-world situations. It can be facilitated through application and practice, such as case studies or simulations.
- **Continuous Improvement.** Continuous improvement is important to help ensure the effectiveness of the microlearning courses over time. Feedback from learners and assessments should be used to refine and improve the content and delivery of the microlearning courses.

How to design Microlearning?

In designing microlearning for RP’s context, a simple 3-step method was introduced to guide staff in their development of microlearning courses.

Step 1: Design

- Identify a suitable learning outcome
- Determine duration, maximum 15 minutes

These questions may be asked when identifying a suitable learning outcome:

- Is this learning outcome specific (e.g., focus on a single topic/problem/context)?
- Is this learning outcome measurable?
- Is this learning outcome achievable within 15 minutes?
- Is this learning outcome realistic (e.g., does it require the use of complex equipment or software)?
- Is this learning outcome timely (i.e., just-in-time to bridge a specific knowledge or skill gap for the learners)?
- Is this learning outcome stand-alone (i.e., it can be learnt independently)?

Step 2: Develop

- Follow the I-D-C (Introduction-Development-Consolidation) cycle

Introduction: Gain attention & share learning outcome

- Share Quote
- Present a Question
- Present a Scenario
- Tell a Story

Development: Present information

- Weblink/Text/Document (max 500 words)
- Video/Audio (max 3 minutes)
- Graphics/Infographics
- Interactive games/simulation

Consolidation:

- Test for Understanding (TFU)
  - Mind-maps, Games, Simulations
  - Puzzles/Matching
  - Multiple Choice/Fill-in-the-blanks, etc.
- Provide Feedback
  - Model answers
  - Real-life Application
  - Areas of improvement
- Facilitates collaboration/discussion (optional)
  - Padlet, Forums

Step 3: Deliver

- Identify suitable digital platform to deliver, e.g.
  - iSpring Marketplace
  - RP's online learning platform (iSpring, Articulate Rise, PPT), etc.

Implementing Microlearning

To validate the workability of the derived framework and test its effectiveness, four microlearning courses, not exceeding 15 minutes each, in the form of SCORM (Sharable Content Object Reference Model) packages, were implemented in a lesson of a module in RP. Refer to Appendix A for the lesson plan of the microlearning courses.

The microlearning courses, were developed using Articulate Rise, a readily available authoring tool. Each course focuses on one learning outcome, using a variety of supplementary media content such as videos and quizzes to enhance knowledge acquisition.

The microlearning courses were released as pre-readings to the lesson on RP's online learning platform and learners were able to go through the courses at their own time and at their own pace.

Qualitative analysis is then performed based on the data collected via focus group discussions with the learners.

Data Analysis Methodology

The interview data from the FGDs was analysed using the three phases of the Grounded Theory methodology in analysing qualitative data.

Phase one is systematic coding, i.e., breaking down of data according to a code list so as to identify relevant and similar patterns (Open coding). The coded segments are then grouped to form more broader categories (Phase two, Axial coding), which in turn, gets linked to more general themes and theoretical concepts (Phase three, Selective coding) that captures the essence of the research. (Corbin and Strauss, 1990).

Results and Discussion

A total of 970 learners attempted the microlearning courses and 27 of them took part in the FGDs, sharing their learning experiences of going through the courses. Refer to Appendix B for the questions used to collect student responses.

The final code system had the following (main) themes to find out if the microlearning approach helps facilitate better learning of the learners:

- Duration
- Comprehension
- Accessibility
- Interactivity

Duration

As technology advances, information gets more readily available and accessible, thus leading to shorter focus time, simply because there is no longer the need for the extra time to search for information. With this, the attention span of people gets shorter.

Participants Feedback	***Findings***
"My attention span is not that long. I cannot like focused very long." "The short SCORMs are fine. the long ones I was doing other things due to having a short attention span." "I prefer short, short, SCORM package because if too long right I think I just want to like finish it like because it's too long really. Then I get bored easily. So yeah, so I prefer short one." "A culture shock to get really short SCORM packages for critical thinking and I want to appreciate and I prefer shorter SCORM packages than really, really long SCORM packages."	One of the attributes of microlearning is the short duration of no more than 15 minutes. This fits learners with shorter attention span as they are better able to stay on the screen and complete the courses. This was affirmed by 19 out of the 27 students who participated in the FGDs.

“Shorter packages give you better retention so that you can ask the questions the next day.”	

Comprehension

Concentration naturally deteriorates with overloading of information, resulting in lower comprehension and knowledge retention, which links to the effect of the Forgetting Curve.

Participants Feedback	***Findings***
“For critical thinking it's more ideal to like break it up into smaller digestible pieces for the students to learn and understand.” “Short and sweet and concise SCORM package will enable me to learn that specific term for that content or that short section or the content, because to me, jumbling all together, sometimes I have to stop halfway and I forget what I've learned before or I miss out on certain parts to remember others.” “Since we've already gone through the pre-readings, …, we can apply it to the problem statement and relate.” “For me, I find the pre-readings very interesting and it's very, not content heavy.” “At some point I may get lost, but at the same time right at certain parts of the SCORM package, I felt that it was quite concise and clear that the packages were trying to put across their points and so.” “I was actually not distracted because I find it quite interesting, is like I was able to apply it well in class.” “The SCORM packages were really that much concise and well-illustrated to the point that there's no need for us to struggle at all.”	Of the 27 students who participated in the FGDs, 18 of them mentioned that the SCORM packages were easy to understand and they were able to better focused on the learning outcomes. Due to the fact that each microlearning course consists of just one learning outcome, the intent is clearer and learners are able to focus better on the topic, as it is deemed simpler and at times, more interesting. Their understanding, too, can be easily verified.

Accessibility

Accessibility in education helps create equal opportunities for all learners. If learning materials are not accessible to learners, then learners' abilities will not be fully developed.

Participants Feedback	***Findings***
“I had to head out for dinner and then even like that, I was able to just complete the SCORM packages, even while I was outside. So, I think they're also like, the short duration of them also makes them like pretty convenient.” “Even the quizzes. Uh, I would say like, fun to do. We're able to try again to get 100%.” “Students can read multiple times and then, I mean, the teacher can actually explain them in class too.” “Sometimes throughout the lessons I still reopen this SCORM packages when I'm in need of the resources.” “Everybody does the SCORM packages at different times sometimes.” “When I do those SCORM packages I'm able to like, go at my own pace.” “I think for me it would be the questions embedded in the learning packages. I can like go and try the questions and then check my understanding and like go back even if I got it wrong, I can go back and check again.”	Microlearning, being offered on a digital platform, is accessible to learners 24/7, allowing them to view the courses at their own convenience, anytime, anywhere. In addition, learners are able to revisit the courses. Of the 27 students who participated in the FGDs, 9 of them appreciated the convenience brought about by the SCORM packages.

Interactivity

Microlearning is best supported with the use of media which has interactive elements to reinforce learning.

Participants Feedback	***Findings***
“I can see, like my classmates' opinion and like I can like see whether I can, you know, agree with the points or because there was there's like a different perspective on the topic itself.” “The discussion at the end of each SCORM packages because is a way for us as students to check our understanding and knowledge with	Different media can be incorporated into microlearning courses. Leveraging on media has created collaborative opportunities

between one another and also to clarify our doubts with one another and at the same time our lecturer can ensure that we actually understood the right concepts." "When we do the SCORM packages on our own, we understand it differently. And when we get together, we can consolidate our learning and get on the same page."	and greatly enhanced interactivity. Of the 27 students who participated in the FGDs, 12 of them found increased interactivity among learners.

Differing Opinions

Despite the many positive feedback for the four microlearning courses, there are also differing opinions that call for areas of improvement.

Being short and concise, the information presented in the microlearning courses may not be detailed enough. As such, learners who prefer traditional courses with more thorough information found little pleasure when going through the courses.

In addition, some learners commented on the lack of more challenging questions and suggested for more variation of activities.

Conclusion

From the results of the FGDs, two-thirds of the participants affirmed that the short duration of the microlearning courses aid in their comprehension of the learning objectives.

The microlearning framework was shown to befit RP's teaching and learning approach, and in general, it was well incorporated into the lessons to complement traditional learning, benefitting the learners and helping them find new confidence and interest for learning.

Whilst there are shortcomings of microlearning, it cannot be denied that the advantages much outweigh the disadvantages.

The proposed microlearning framework in the implemented lesson was one that worked for majority of the learners, and it deserves to be further explored for other courses and schools within RP to further assess the effectiveness of microlearning. More detailed planning of the curriculum and activities as well as meticulous selection of suitable learning outcomes must be carried out to fully realise the potential of microlearning.

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APPENDIX A

Learning Outcomes	• Recognise characteristics of complex problems • Analyse complex problems using tools such as 5-whys and nested systems • Explain quick fixes and their unintended consequences
Description of the four microlearning courses implemented as pre-reading for the lesson	**Microlearning course 1 - Applying Nested Systems to a complex problem** By the end of this microlearning course, learners should be able to use the Nested Systems tool to analyse a complex problem. This course takes about 10 minutes to complete and includes a Practice Quiz. **Microlearning course 2 - Finding the Root Cause of a Problem** By the end of this microlearning course, learners should be able to: • Use the 5-whys method to analyze a problem • Identify the root cause of a problem using the 5-whys method This course takes about 10 minutes to complete and covers the below: • Wait, so what's the REAL problem? • How to use the 5-whys method? • What is the root cause of a problem? • Practice Quiz **Microlearning course 3 - Recognising Complex Problems** By the end of this microlearning course, you should be able to: • Recognise the characteristics of a complex problem • Appreciate how systems thinking can help us analyse a complex problem This course takes about 10 minutes to complete and covers: • What makes a problem complex? • What is systems thinking? • Practice Quiz **Microlearning course 4 - Solving Complex Problems** By the end of this microlearning course, you should be able to propose long-term solution(s) that address a complex problem. This course takes about 10 minutes to complete and covers: • Long term vs short term solutions • Unintended consequences • Practice Quiz

APPENDIX B

Research Purpose:
Develop a conceptual framework of Microlearning (ML) for Republic Polytechnic's learner-centred environments.

Research Objective:
To develop a conceptual framework for ML at Republic Polytechnic that covers:

- What is Microlearning?
- Why should Microlearning be implemented in the curriculum?
- What are the key features of Microlearning?
- How to implement Microlearning?

Purpose of Focus Group Discussions (FGDs):

- Gathering feedback from students for ML SCORM packages implemented in a lesson of a module on critical thinking and problem-solving skills in AY2022 Semester 2.
- Gain useful insights into the learner's reaction and learning through ML SCORM packages implemented

Research Questions:
FGDs are to gain insights into the research questions listed below. The discussions should be based on the 4 ML SCORM packages implemented.

- How do the students experience the Microlearning SCORM packages?
- How do the students learn through the Microlearning SCORM packages?

Number of Student FGDs: Five, 3 to 7 students in each group

Questions for Student FGDs: Objective of the FGDs is to get the answers to the "why" and "how" microlearning course have helped them understanding the lesson.

Category	**Questions**
Learning Outcomes	• How was the learning experience for you when going through the SCORM packages for lesson 5? • Did the SCORM packages meet your learning needs at that point in time? Explain.
Micro-SCORM materials	• What did you find different between lesson 5 SCORM packages and usual SCORM packages? • In your opinion, what type of activities do you prefer for pre-readings?
Relevance	• Were you able to relate the SCORM package to each of the learning outcomes? Why or why not?
Knowledge/skills acquisition	• Do you feel the SCORM packages equipped you with the knowledge needed to achieve the learning outcomes for the lessons? Explain. • How did you find the duration of the SCORM packages?
Collaboration	• Explain whether the SCORM packages give you the opportunity to collaborate** with your peers. • Explain whether the SCORM packages give you the opportunity to collaborate** with your lecturers. *** padlet and discussion forums were used for collaboration. Moderator to probe further on the use of the collaboration opportunities.*
Other insights/ engagement/interaction/ challenges in attempting SCORM etc.	• Were you actively involved during the course of prereading SCORM packages? Explain. • What improvements would you suggest for the SCORM packages? E.g. duration, activities, content coverage, interaction, etc. • Would you prefer a series of shorter SCORM packages in your module or would you prefer longer SCORM packages? Explain.

INTERACTIVE ONLINE EXERCISES WITH SELF-DIRECTED LEARNING STRATEGIES

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Abstract

Practice is essential to improve learners' acquisition of mathematical knowledge and skills. For the freshman Mathematics module in a Polytechnic in Singapore, exercise questions in PDF format have been provided as a form of further practice, which learners solve, after class, in their own time. As technology advances, e-learning platforms can be utilised, along with adaptive learning technology, to enhance learners' engagement in solving these exercise or practice questions.

Our study utilises the in-house creation of interactive online exercises in the Sharable Content Object Reference Model (SCORM) format with the incorporation of self-directed learning (SDL) strategies to improve learners' SDL abilities. A quantitative research design was used to investigate how implementing these SCORM exercises with SDL lesson design strategies impacts learners' SDL abilities, mathematical knowledge, and skills.

Results reveal that learners who attempted six or more SCORM exercises have significantly improved their mathematical knowledge, skills, and SDL abilities.

Keywords: *E-Learning, Adaptive Learning, Self-Directed Learning, SCORM, Mathematics*

Introduction

Several scholars assert that practice is critical to improving the ability to solve mathematical tasks (Sigmundsson & Loras, 2013). For example, in two classroom experiments by Emeny et al. (2021), practice spaced out has consistently improved the mathematics test scores of learners in both experiments.

With rapidly evolving technological advances, educational institutions have increasingly used up-to-date technology to teach and learn mathematics. Computer-assisted learning (CAL) is one of them, as it involves using computers to enhance learning via computerised instruction, drills and exercises. De Witte et al. (2015) affirmed the positive impact of the CAL in learning mathematics when they found that schools that frequently used CAL had higher test outcomes. Lai et al. (2015) similarly discovered that remedial CAL outside of regular school hours improved the learner's mathematics scores and increased their interest in learning. Furthermore, a comparison of different interventions for learners with mathematical difficulties showed that computer-based practice effectively improves mathematics proficiency and is a valuable tool for reviewing mathematical concepts taught in earlier lessons (Kanive et al., 2014).

Alotaibi and Alanazi (2021) highlighted that learners with a highly fragmented conception of mathematics tend to have low SDL skills and, in turn, low mathematics achievement. In contrast, learners with a highly cohesive concept of mathematics tend to have high SDL skills and, in turn, high mathematics achievement. Another study that investigated the relationship between three components of SDL in online learning found that motivation directly affected self-monitoring and indirectly influenced self-management through self-monitoring. In addition, self-monitoring positively influences self-management (Zhu et al., 2020). Therefore, equipping learners with mathematical knowledge and SDL skills is vital to enhancing their performance in mathematics.

Despite the recognized benefits and growing interest in using adaptive learning technology in teaching, its broad implementation remains somewhat limited. The review of previous studies shows that higher educational institutions face various barriers and challenges when testing or adopting adaptive learning tools. The main challenges discussed in the literature are related to technology and pedagogy (e.g., Bailey et al., 2018; Johnson & Zone, 2018; Zliobaite et al., 2012). Major technological challenges involve, for example, dealing with real-time data (Zliobaite et al., 2012), difficulties in integrating adaptive learning solutions into existing learning management systems (LMS), the complexity of adaptive systems and their ease of use or usability (Dziuban et al., 2018; Tyton Partners, 2016). Some pedagogical challenges relate to the need to redesign the curriculum (Educause, 2017) and the role of faculty in the adoption process (Oxman & Wong, 2014; Tyton Partners, 2016).

One commonly cited challenge is faculty engagement. When first exposed to the adaptive approach, faculties often resist using technology

(Johnson & Zone, 2018). In many cases, faculties express concerns about the benefits of adaptive learning, their diminishing role in a course design, loss of control over courses, and additional workload (Hall Giesinger, 2016; Izumi, Fathers & Clemens, 2013; Johnson & Zone, 2018; Tyton Partners, 2016). In the phase of piloting adaptive learning, faculties often struggle with using adaptive software for communicating with students and modifying learning content (O'Sullivan, 2018). Weber (2019) reflected on the slow adoption progress and concluded that today's primary challenge is the massive investment in time, money and resources resulting from the complexity of adaptive technology. Other concerns include high licensing fees and long-lasting scepticism of faculties towards its potential disruption in education in general.

To address the identified gaps, the project team created carefully selected and curated sets of in-house interactive online exercises using the SCORM format, which is cost-efficient, less time-consuming and less resource intensive. Furthermore, the ownership and direct access to the SCORM exercises afford the creators the flexibility to craft their questions suited towards relevant coverage and address the difficulty across various content segments within the module. Additionally, learners do not need to familiarise themselves with another new platform to attempt these SCORM exercises. Finally, to facilitate monitoring of learners' progress, the project team developed a dashboard, entailing learners' progress in the SCORM exercises, ensuring easy access for lecturers to monitor learners' progress.

Methodology

This study addresses the following research questions:
RQ1: How do SCORM exercises impact learners' acquisition of mathematical knowledge and skills?
RQ2: How do SDL strategies incorporated in lesson design affect learners' SDL abilities?

A quantitative research design was employed to analyze the impact of SCORM exercises on the acquisition of knowledge and skills and the learners' SDL competencies across seven dimensions, namely, Assess Task, Evaluate Expertise, Plan Approach, Monitor Progress, Adjust Strategies, Learning Motivation and Collaborative Communication (Vedamuthu & Periasamy, 2022) in the module over the first semester.

The SCORM exercises featured the following design considerations to help learners with their after-lesson practice:

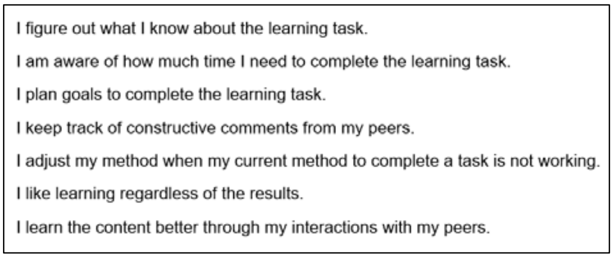
- Clear instructions highlighting the outcomes, their importance and steps towards achieving them. This aligns with the Assess Task dimension of SDL.
- A plan is provided with a suggested timeline to complete each activity that ranges from easy to difficult. This aligns with the Plan Approach dimension of SDL.
- Hints are provided when learners get their first attempt wrong, and they are given a chance to reattempt the question. This aligns with the Evaluate Expertise dimension of SDL.
- Worked solutions are provided after learners answer each exercise question, regardless of the accuracy of the final answer. In addition, a simple two-item self-evaluation checklist is provided for learners to reflect on whether they met the suggested timeline and achieved the outcomes. This aligns with the Monitor Progress dimension of SDL.
- Learners can attempt a similar question again after answering it incorrectly or proceed to a different one. At the end of the exercise, learners can either review their quiz answers, view a detailed report of the quiz or retry the entire quiz (unlimited attempts). This aligns with the Adjust Strategy dimension of SDL.
- The SCORM exercises were made (1) interesting and relevant, (2) feedback showed relevance to learners' current academic lives and future professional lives, and (3) questions were designed to build on prior knowledge and made to mirror similar competency levels as in the quizzes. This aligns with the Learning motivation dimension of SDL.

Lecturers received weekly feedback about learners' performances on the SCORM exercises. They viewed these statistics on a dashboard identifying learners requiring additional help or specific topics that need more elaboration.

Quantitative Methods

The SDL skills of the learners were measured using an online survey based on the established 7-factor SDL index, comprising 34 indicators. Figure 1 shows the example of 7 indicators from each of the seven dimensions. A 5-point Likert scale was used in the survey, and data was collected in Lesson 04 and Lesson 12. A total of 1456 learners participated in the first survey, while 1106 learners participated in the second survey. Out of these learners, 727 learners participated in both surveys.

Figure 1: Seven of the indicators in the online survey



I figure out what I know about the learning task.

I am aware of how much time I need to complete the learning task.

I plan goals to complete the learning task.

I keep track of constructive comments from my peers.

I adjust my method when my current method to complete a task is not working.

I like learning regardless of the results.

I learn the content better through my interactions with my peers.

After the completion of each lesson, SCORM exercises covering the lesson's topics were given to learners as further practice. These were not part of the lesson's deliverables. The SCORM exercises were not graded and did not account for the Continuous Assessment grades of the learners. The SCORM exercise completion rate report was used to track each learner's number of exercises before the Mid-Semester (MSA) and End-Semester Assessment (ESE). For analysis, learners'

MSA scores, ESE scores, and raw module scores from all 2383 learners were collected.

The completion rate of the SCORM exercises was high, with 58% of learners completing six or more exercises before ESE (Figure 2). Figure 3 outlines the data collection timeline.

Figure 2: Completion rate of SCORM exercises

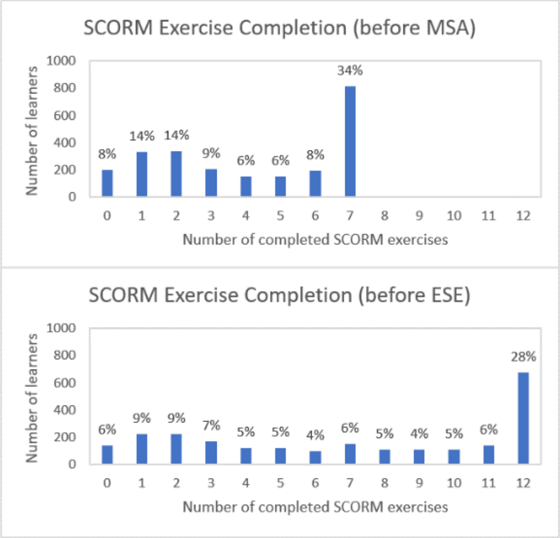


Figure 3: Data collection timeline

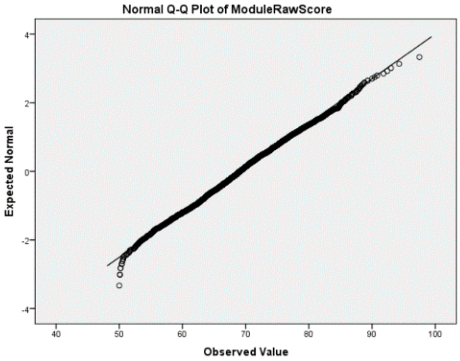
Three independent sample t-tests were carried out for two groups on MSA scores, ESE scores and module raw scores to analyse the impact of the SCORM exercises on learners' academic performance (Table 1). Group 1 completed six or more SCORM exercises, and Group 2 completed three or fewer SCORM exercises.

Two more independent sample t-tests were done on the raw module scores, consisting of high-performing learners with module grades A, B+ and B, and the other for average / below-average learners with module grades of C+, C, D+ and D (Table 2). This is to investigate the impact of the SCORM exercises on learners with different academic abilities.

Paired sample t-test was carried out on the two SDL survey scores of learners who have completed six or more SCORM exercises to study the impact of the SCORM exercise on learners' SDL competencies. Data cleaning was done to remove disengaged responses (Curran, 2015; Huang et al., 2015).

Normality has been satisfied for all the above tests. An example of the normal Q-Q plot for the raw module score is shown in Figure 4, where the observed values match closely to the expected normal.

Figure 3: Normal Q-Q plot of module raw score



Results and Discussion

Table 1 summarises the findings of the three independent sample t-tests. The learners who completed six or more SCORM exercises (Group 1) had consistently obtained significantly higher MSA scores, ESE scores and raw module scores, respectively, than those who completed three or fewer SCORM exercises (Group 2).

Table 1: Independent sample t-tests on MSA scores, ESE scores and raw module scores

	Group	*N*	Mean	*SD*	*t*
MSA score	1*	1010	66.3	14.5	15.0***
	2**	1073	55.9	17.0	
ESE score	1*	1390	70.0	10.9	13.6***
	2**	757	61.4	15.4	
Module raw score	1*	1390	70.8	7.78	15.2***
	2**	757	63.9	11.0	

*Group 1 completed six or more SCORM exercises
**Group 2 completed three or fewer SCORM exercises
***$p < 0.001$

Table 2 shows the comparison between high-performing and average / below-average learners. The independent sample t-tests revealed that learners of all proficiency levels across both clusters who completed six or more SCORM exercises showed improvement in their raw module scores.

Table 2: Independent sample t-tests for high-performing learners and average / below-average learners

	Group	*N*	Mean	*SD*	*t*
Module raw score (learners who scored A, B+, B)	1*	739	76.4	4.91	5.51***
	2**	199	74.6	3.76	
Module raw score (learners who scored C+, C, D+, D)	1*	645	64.6	4.34	6.69***
	2**	498	62.7	4.97	

*Group 1 completed six or more SCORM exercises
**Group 2 completed three or fewer SCORM exercises
***$p < 0.001$

Results from the paired sample t-test on the two SDL survey scores (1st survey: M = 4.00, SD = 0.52; 2nd survey: M = 4.11; SD = 0.56) of learners who have completed six or more SCORM exercises indicate that completing SCORM exercises improves the SDL abilities of the learners, t(432) = 4.28, p < .001.

All results showed that SCORM exercises positively impact learners' acquisition of mathematical knowledge and skills and their SDL abilities, which answered research questions RQ1 and RQ2.

Conclusion

Quantitative results revealed that learners who have completed six or more SCORM exercises have significantly improved SDL abilities and academic performance in mathematics. The development of in-house SCORM exercises has received encouraging feedback from learners, with high completion rates and improved academic performance and SDL abilities. It is recommended that interactive online exercises in SCORM format be included in technical modules (such as mathematics, physics, mechanics, principles of electronics, etc.) to improve learners' academic performance and SDL abilities significantly.

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MAXIMIZING LEARNER SUCCESS IN MATHEMATICS WITH DIFFERENTIATED BLENDED LEARNING

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Abstract

While Covid-19 pandemic in 2020 saw all lessons moved online out of necessity, Singapore IHLs' leverage on the affordances of blended learning remains elevated when the safe management measures have been lifted. In this paper, the author will share his experience in implementing differentiated instruction with blended learning for 500 mixed-ability stage 1 learners in all IT-based diplomas in their learning of mathematics in the form of asynchronous online lecture and in-person tutorial. Differentiated learning during asynchronous online lecture is achieved with the use of bite-sized content, a mixed of media-like text, infographics and instructional videos where learners can view and review them at their own time and pace. This, augment with monitoring of learners' performance in learning-validation questions to address learning gaps at start of associated tutorial, help to ensure learners with mixed abilities are adequately and effectively prepared to partake and benefit from the active learning activities during tutorial. Through active engagement and interaction with learners during in-person tutorial classes averaging 20 learners, the tutor is able to further differentiate and monitor individual learner's progress to provide immediate feedback and to identify learners who needed more attention and provide them with the necessary help while the faster learners are given additional challenging questions to stretch them further. The use of ALERT (Assessing Learning in Real Time) system at end of most learning topics allows learners to provide feedback on what they have learnt and raise question they might still have, to enable instructor to follow up and respond to those who still need clarification or further assistance. The author will further share his recommendations for an effective and engaging differentiated blended learning which include using multiple types of instructional materials, leveraging on technology to identify online learning behavioural patterns and mixing up group composition in aspect of ability during in-person tutorials. The author reckons the education research paper will benefit technical institutes who wishes to implement differentiated blended learning in the teaching and learning of mathematics to mixed-ability learners.

Keywords: *Differentiated Learning, Blended Learning, Asynchronous Online Lecture, Flexible Grouping, Active Classroom Learning.*

Introduction

Differentiated learning, also commonly known as differentiated instruction, is an instructional approach which fits individual learners' needs using various techniques such as adjusting the content, the learning process, the learning environment or the product (expected learners' task or artefact to be generated) Tomlinson (2005), a leading expert in this field, defines differentiated instruction as a philosophy of teaching that is based on the premise that learners learn best when their instructors accommodate the differences in their readiness levels, interests and learning profiles. A chief objective of differentiated instruction is to take full advantage of learner's ability to learn (Tomlinson, 2001 & 2005). It presents an effective means to address learner variance as well as provides a crucial platform for all instructors of inclusive classrooms, to create opportunities for success for all learners (Tomlinson, 2000). Instructor can carry out differentiated learning though content, process, product and learning environment (Tomlinson, 2001). Research on the effectiveness of differentiation shows that differentiated learning benefits a wide range of learners, from those with learning disabilities to those who are considered high ability.

Blended learning is a kind of instruction that combines conventional, in-person instruction methods with online learning opportunities (Lawless, 2019). It is a combination of digital and face-to-face content delivery method (Graham, 2006), but on the continuum from face-to-face to online, the nature of its hybridness is still up for debate. The author construes blended learning as the combination of asynchronous online lecture (AOL) with in-person active learning to provide learners with more control over the time, place, pace and path of their learning. Studies have shown that the use of blended-based instruction allows more learners engagement and increases learners' participation (Bowyer & Chambers, 2017).

In this paper, the author explores and shares his experience on how blended learning can support the implementation of differentiate learning to a cohort of 500 mixed-ability freshmen in School of IT, Nanyang Polytechnic in the teaching and learning of Mathematics.

Background

The School of Information Technology, Nanyang Polytechnic takes in approximately 500 freshmen (more commonly known as stage 1 learners) into its five IT-based diploma courses in every academic year. These learners are enrolled from different admission schemes which include but not limited to JAE (Joint Admission Exercises) for learners from secondary schools who took GCE 'O' level exam, JPAE (Joint Polytechnic Admission Exercises, for learners from ITE (Institute of Technical Education), PFP (Polytechnic Foundation Programme) for learners who took GCE 'N' level exam and spent a year in polytechnic doing foundation modules, EAE (Early Admission Exercise) which is an aptitude-based admissions exercise for learners from secondary schools and ITE, and DAE (Direct Admission Exercise) for learners from junior colleges who did GCE 'A' level exam or IB (International Baccalaureate) diploma programme or other equivalent post-secondary qualifications.

In the School of IT, Nanyang Polytechnic, mathematics is core for all stage 1 learners where they study Computing Mathematics in semester 1 and Business Statistics in semester 2. The different admission paths with corresponding varied mathematics exposure rendered a cohort of stage 1 learners with diverse abilities and needs, with topical weaker learners experiencing challenges in mathematics competency. Against this backdrop, the author implemented differentiated instructions with blended learning in the teaching and learning of Business Statistic in semester 2 of academic year 2022 to address the mixed-ability of these stage 1 learners which differ in their readiness, interests and learning profiles. With the experience gained and lesson learnt from this implementation, the author and his team will also be introducing differentiated blended learning in Computing Mathematics in the coming semester 1 of academic year 2023.

Pedagogy

Blended learning is an education strategy that features multiple teaching methods to help learners learn more effectively than one method on its own (Stauffer, 2022). In most cases, blended learning combines a mixed of online learning and traditional classroom learning. In our context, blended learning is the combination of asynchronous online lecture (AOL) with in-person active learning in tutorial classes, to provide learners with more control over the time, place, pace and path of their learning. In this blended learning approach, asynchronous online lecture is used to introduce and reinforce statistical concepts while the in-person tutorial is used to provide hands-on practice and collaborative learning through group activity to solve problem sums in statistics.

Differentiated Learning in AOL

Differentiated learning during AOL is achieved with the help of Brightspace, a web-based Learning Management System (LMS) where learners can view and review the bite-sized learning content at their own time, place and pace. The bite-size content consists of a mixed of media-like text, infographics and instructional videos that introduce statistical concepts, developed using Articulate Rise 360, a web-based course authoring software. Brightspace's Analytics Tools of Course Access, Content Report, Class Progress and Class Engagement were used to track the learners' progress and activity in log-in time and duration, access of content topics, participation in quizzes and assignment submission. The use of Brightspace's Course Tools of Intelligent Agents further helped to alert instructor on learners who were falling behind in their learning (e.g. Intelligent Agents automatically send notification to learners who has not log in the system for 7 days). More importantly, learners' performance is monitored through learning-validation questions embedded in every topic of AOL to allow instructor to address learning gaps at start of associated tutorial and to ensure learners with mixed ability were adequately prepared to partake in and benefit from the learning activities during tutorials.

Differentiated Learning in In-Person Tutorial

A hallmark of an effective differentiated classroom is the use of flexible grouping which accommodates learners who are strong in some areas and weaker in others. The instructor uses different group configurations over time, and learners experience many different working groups and arrangements (Tomlinson, 2001). Flexible grouping is a teaching practice that allows learners to team up according to ability, allowing the instructor to focus on certain learning objectives according to learner need to make differentiated learning possible (Miller, 2018). The average Business Statistics tutorial class size is 20 learners. By leveraging on differentiated learning tactic of flexible grouping, with each group consisting of 4 to 5 learners, instructor is able to use the differences in ability of learners to better accelerate learning of selected topics in tutorial. Depending on learning objective and topic, instructor organized learners into homogeneous groups (where learners are grouped according to their ability levels) to facilitate group-based differentiated learning or organized them into heterogeneous groups (where learners of all ability levels are represented in each group) to promote collaborative learning. In homogenous grouping, instructor assumed the role of facilitator and moved around in class to guide group that might need help or clarification and to encourage interaction and cooperation among group members. In heterogeneous grouping, each member of the group is responsible not only for learning what is taught but also for helping other group members learn. Learners work through the task of solving tutorial questions until all group members successfully understand and complete it.

While flexible grouping enabled learners of similar or complementary levels to work together and collaborate where they learned and progressed as a group, differentiated learning for individual learner continue to occur even when there is no group learning activity. Through active engagement and interaction with learners, instructor was able to differentiate and monitor individual learning to provide immediate feedback and to identify learners who needed more help while faster learners were given additional challenging tutorial questions to stretch them further. Two differentiated learning tactics were deployed to allow mixed-ability learners to maximize learning during in-person tutorial: Tiered Activity which teaches the same statistical concept but at varying levels or degrees of challenge by considering the learners' ability, and Anchor Activity that learners performed when they have completed assigned task of solving tutorial questions or when the instructor is busy with other learners to provide time for instructor to offer specific help and instruction to learners requiring additional assistance.

The use of ALERT (Assessing Learning in Real Time) system at end of tutorial for many topics allowed learners to provide feedback on what they have learnt and raise question they might still have, to allow instructor to follow up and respond to those who still needed clarification or required further assistance. ALERT is a joint project developed by the polytechnics and Institute of Technical Education in Singapore to assess learning in real time and to provide timely response to the feedback. It solicits quick feedback from learners via QR code on three questions on lesson just conducted: percentage of content learner understood, a word best described how learner felt, and a specific question learner would like to ask. With the help of insightful dashboard, ALERT helps instructor to determine if a lesson is well understood and find out how to improve a lesson. More significantly, it enables instructor to provide targeted help to individual learner which is an important facet of differentiated learning for mix-ability learners.

Results and Discussion

In this section, the author shares the finding on the measuring metrics of learning effectiveness and learner satisfaction to appraise the level of success of implementing differentiated blended learning in Business Statistics. The success of a pedagogy does not rest solely on its ability to improve on learning effectiveness but also on learner satisfaction. For learning effectiveness, the author examined the passing rate and mean score of the module result of this semester vis-a-vis the previous semester when differentiated learning was not yet implemented. Learner feedback was conducted to measure the learner satisfaction using the Module Evaluation and Feedback System (MEFS).

The author compared the academic performance in Business Statistics module between academic year 2022 and academic year 2020 when differentiated learning was not yet implemented, focusing on the module passing rate (Figure 1) and the module mean score (Figure 2).

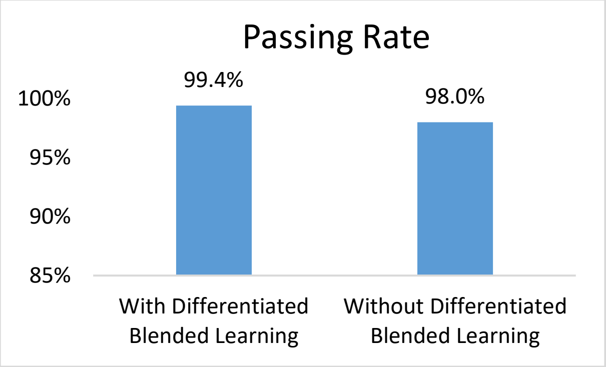

Figure 1: *Comparing Passing Rate of Business Statistics when differentiated blended learning was implemented and when it has not been implemented.*

Figure 1 above shows the result of the passing rate of Business Statistics when differentiated instruction in blended learning was implemented in academic year 2022 (99.4%) and when it was not implemented in 2020 (98.0%). From Figure 1, we can see that there is an improvement of 1.4% in passing rate of learners. The author also compared the mean score of Business Statistics between the aforementioned two years and the result is shown in Figure 2 below.

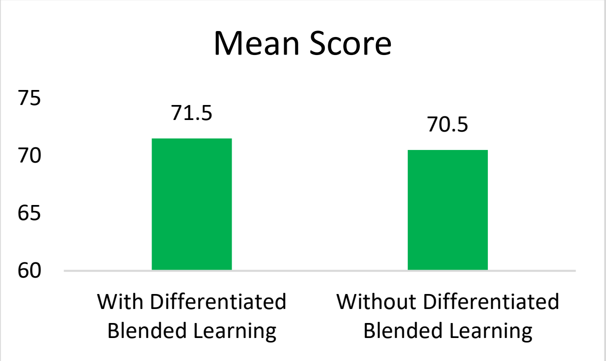

Figure 2: *Comparing Mean Score of Business Statistics when differentiated blended learning was implemented and when it has not been implemented.*

From Figure 2, we can see that the differentiated instruction in blended learning has mean score of 71.5 marks in 2022 over 70.5 marks in 2020, an improvement of 1 mark. The effect size of the mean score (Cohen's d) for measuring the magnitude of difference in mean between the two groups is computed to be 0.11, indicating a small effect of differentiated blended learning in the improvement of mean score.

The level of student satisfaction was based on the learner feedback collected via MEFS in the form of online survey. The result is shown in Figure 3 below.

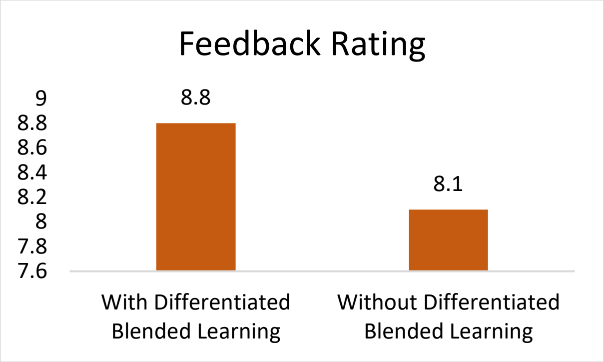

***Figure** 3: Comparing Learner Satisfaction in Business Statistics when differentiated blended learning was implemented and when it has not been implemented.*

The effect size of the mean score (Cohen's d) for measuring the magnitude of difference in feedback rating between the two groups is computed to be 0.44, indicating a medium effect of differentiated blended learning in the improvement of learner satisfaction and learning experiences. Qualitative feedback comments from learners reveal that learners are very satisfied that the learning process and content are tailored to their learning pace and readiness. The improvement in passing rate and mean score as well as learner satisfaction, albeit small to moderate effect, can be attributed to the learning effectiveness of differentiated learning where learners can view and review the learning content at their own learning time, place and pace, the in-person active learning activity in tutorial with flexible grouping and differentiated learning tactic, as well as the timely and personalized feedback they received on their performance in AOL and during in-person tutorial.

Conclusion and Recommendation

The research established that differentiated instruction in blending learning supports mixed-ability learners as a community, accommodating differences and sameness. By addressing the differences of mixed-ability learners in their readiness, interest and learning profile, instructor can maximize their learning potential in the learning of Business Statistics. When learners were given more options on how they could learn, they took on more responsibility for their own learning and appeared to be more engaged in learning.

In AOL, the bite-size interactive learning content is delivered asynchronously where learners can view and review them at their own pace, time and place. This form of *process differentiation* has shown to be effective in meeting the needs of mixed-ability learners. It is essential to build in learning-validation questions in AOL to monitor the progress and performance of learners and to address the learning gaps, if any, at start of associated tutorial to ensure all learners are adequately prepared to partake and benefit from the individual and group learning activities during tutorial.

In in-person tutorial, the deployment of flexible grouping allowed learners to group based on their ability through homogeneous or heterogeneous grouping, allowing instructor to focus on certain objectives to make differentiated instruction possible for mixed-ability learners. However, it is imperative that the grouping is done discreetly in stealth mode so that learners do not know the difference. This is because many learners who are struggling with a new concept do not necessarily want their peers to know and will do anything to cover up the fact that they are lost. It is thus crucial for instructor to use appropriate classroom management techniques such as the one just cited to ensure a safe and positive learning environment for all learners. Flexible grouping, coupled with differentiated tactics of tiered activity and anchor activity, have shown to be effective and engaging as a *content differentiation* strategy that maximizes the learning success of mixed-ability learners. It is equally important to encourage and entice learners to provide feedback at the end of tutorial for selected topics (via ALERT system) to allow instructor to follow up and respond to those who still need clarification or further assistance.

With the successful implementation of process differentiation and content differentiation for blended learning in the teaching and learning of Business Statistics, the author will be looking forward to implementing *learning environment differentiation* for mixed-ability learners in the next academic year in Computing Mathematics to leverage on the newly available learning spaces that are equipped with flexible furniture arrangement and smart interactive boards to support individual work preferences and to facilitate collaborative learning, in addition to a safe and positive learning environment. Further research into *product differentiation* as a form of differentiated assessment could be look into as additional lever for learning differentiation to benefit the learners.

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Enhanced Learning Performance and Learning Experience in Differential Equations using Adaptive Learning Technology

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Abstract

Classrooms today have learners with diverse learning preferences and backgrounds, making the traditional teaching methods inadequate. These methods disregard individual learning styles, pace, and strengths, causing some learners to fall behind or lose interest. To effectively support learning, personalized and inclusive teaching strategies are crucial. Adaptive learning personalizes education by providing tailored content, targeted focus on specific areas and frequent practice, resulting in immediate feedback, leading to improved learning outcomes.

In this study, we used the adaptive learning process in Brightspace AI suite to design lessons on two topics related to Differential Equations for 86 learners from the Diploma in Electronic & Computer Engineering at Nanyang Polytechnic in Singapore. The adaptive system adjusted the content to each learner's strengths and weaknesses, providing personalized questions for practice and assessment. Learners were able to track their progress and identify areas for improvement. If learners answered a question incorrectly, the adaptive system provides the correct answer and suggests additional reading materials for learners to gain better understanding.

Learners' performance in the two topics and their learning experience were evaluated through pre- and post-tests and a survey. The results showed a significant improvement in learners' performance and many positive intangible benefits, such as an improved confidence level in solving mathematical problems and more efficient use of time in learning. This paper presents findings and recommendations for implementing adaptive learning in education.

Keywords: adaptive learning, digital transformation in engineering education, personalised learning plan, self-learning

Introduction

A review of the literature shows learning as a class is not always ideal and effective because each learner has different learning pace and needs (Kaminskiene & DeUrraza, 2020). Our learners at the School of Engineering, Nanyang Polytechnic, come from diverse educational backgrounds, including GCE 'O' and 'A' level holders, Institute of Technical Education (ITE) graduates, Integrated Programmed (IP) students, and adult learners from the industry. Teaching at the right pace is challenging due to the diversity of learners in our classes. With an average class size of twenty-two learners per teacher, it can be difficult to give individual attention to each learner (Ministry of Education, 2020). Structured curriculum and lesson time also limits learners' ability to reflect, internalise, and apply their learning (Kapp, 2016). There is an increasing demand for a more innovative and effective approach using technology to address diversity in the classroom, to meet learning expectations and improve learning outcomes.

Adaptive learning is an approach that utilizes technology or systems to monitor learner progress and use data to modify teaching content based on individual learner behaviour and needs (Becker et al., 2018). This approach aims to provide a personalized learning experience for each learner, which is tailored to their unique needs, abilities, and learning styles. To achieve this, real-time assessment, data analysis, and machine learning techniques are used to continuously adjust the learning path based on ongoing feedback from the learner (Baker, 2012). AI-driven assessments are particularly useful in providing feedback on learner performance and progress (Chassignol et al., 2018). Based on the 'report card', the adaptive learning tool generates personalised study paths for the learners, recommending the most relevant materials to bridge gaps in knowledge and focus on areas where they need improvement. Brightspace LeaP is an adaptive learning technology that allows instructors to personalize learning for each learner by creating a knowledge map that outlines adaptive pathways (Schaffhauser, 2014). This adaptive feature is made possible by AI analytics that monitor learner progress and automatically adjust the learning path based on their results. This personalized approach can help learners achieve better outcomes and improve their overall learning experience. However, this technology is relatively new to the polytechnic educators and more research is needed to fully understand its impact.

Approach and Implementation

Nanyang Polytechnic adopted the Brightspace Learning Management System in April 2022. Brightspace suites come with intelligent agents that allow the instructor to provide personalized learning paths for learners.

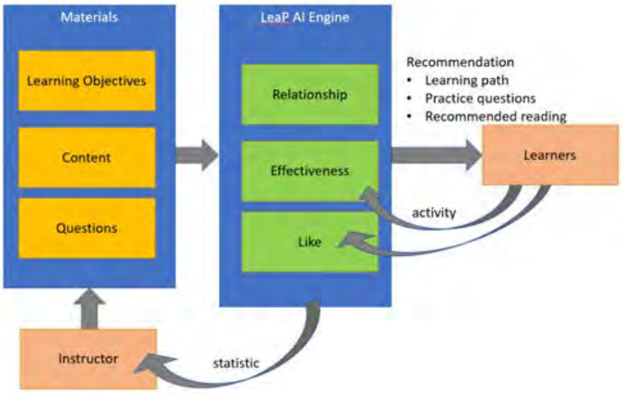


Figure 1 Adaptive Learning AI

The approach to develop the adaptive learning using Brightspace is as follows:

1. The instructor is to define the learning objectives to track the knowledge that learners acquire in the learning.

Table 1 Define Learning Objectives

TID	Parent ID	Title	Description	Leaf?
1	0	Calculus	Calculus	
2	1	Multi-variable Functions	Differentiate multi-variable functions	
3	2	Partial Derivatives	Partial Derivatives	y
4	2	Chain Rule	Chain Rule	y
5	1	Integration by Parts	Integration by Parts	
6	5	Formula	Integration by Parts Formula	y
7	5	DI	DI method	y
8	5	DD	DD method	y

2. Using Brightspace's AI suite, the adaptive learning engine maps the content materials and questions in the question bank to the learning objectives semantically. (see Figure 2)

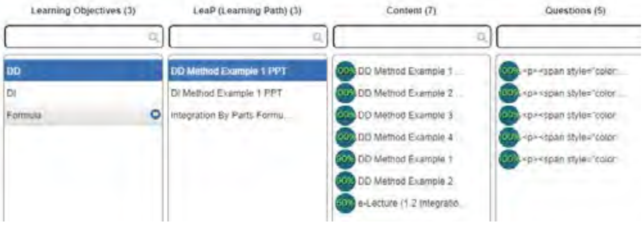


Figure 2 Automatic mapping of content and questions to learning objectives using AI

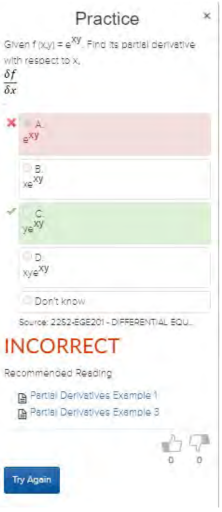
3. Learners are required to take a diagnostic test when they first launch the adaptive learning program. Based on the diagnostic test results, the AI filters out content related to learning objectives that a learner has already demonstrated knowledge of, so that the learner only needs to focus on what he does not know specifically.

Figure 3 Diagnostic test

4. The adaptive engine generates personalised learning plan (learning path) for each learner based on the success rate of learners answering the test questions. It suggests recommended study materials based on relevance to the learning objectives, effectiveness in helping the learner answer questions correctly, and the number of "likes" awarded by other learners.

Figure 4 Personalised Learning Plan

5. Learners have the option to access additional recommended readings and practice questions to further improve their understanding. The "learning-testing-reinforcing" cycles guide the learner towards mastery of the material.


Practice

Given f (x,y) = e^{xy}. Find its partial derivative with respect to x,

$\frac{\delta f}{\delta x}$

○ A. e^{xy}

○ B. xe^{xy}

○ C. ye^{xy}

○ D. xye^{xy}

○ Don't know

Source: 2252-EGE201 - DIFFERENTIAL EQU...

INCORRECT

Recommended Reading

Partial Derivatives Example 1

Partial Derivatives Example 3

Figure 5 Practice Questions

Participants

This study involved 86 second-year learners, aged 18 to 25, from the Diploma in Electronic & Computer Engineering (DECE). The average class size was 22, with 7% of the participants repeating the module and 6% having special learning needs. The learners' GPA ranged from 0.74 to 3.91, representing a diverse range of academic abilities.

Methodology

The research design for this study was a pre-post test within group design, which was suitable for evaluating the impact of an intervention using adaptive learning tool on a dependent variable (learners' performance). The study encompassed two topics in the Engineering Mathematics module: Differential Equations and Series. The control group in this study consists of learners who attended the same lecturer and tutorials but did not use the adaptive learning tool. The learners attended lectures and tutorials, followed by a pre-test on the topic covered. They used lecture notes and tutorial materials to study for the test. Subsequently, the experimental group, which consists of the same group of learners, was introduced to the adaptive learning tool and given a week to use it to improve their understanding. After a week, a post-test was administered to assess their performance. This process was repeated for the second topic to observe any differences in results. At the end of the study, learners completed a survey to assess their learning experience.

Results and Discussion

The data revealed that adaptive learning improves learning outcomes. Average scores increased by 16%, passing rate by 20%, and a higher number of learners scored grade B and above. This shows that adaptive learning leads to better performance for learners.

Based on the data captured, we found a more significant improvement among learners who scored less than 50% in the pre-test. Their scores improved by an average of 35.4%. Adaptive learning reduces the performance gap between the low and high performers by helping the learners to progress towards mastery.

T-tests revealed a significant difference between pre-test and post-test performance for both topics. For topic 1, the t-value was 3.12 which gave a p-value of 0.0011; For topic 2, the t-value was 3.10 which gave a p-value of 0.0012; A p-value of less than 0.05 is customarily deemed as statistically significant. Therefore, the results demonstrate an overall significant difference between the pre-test and post-test. The outcomes are consistent for both topics. This indicates adaptive learning is effective in improving learners' performance.

Table 2 Data analysis (T-test)

Topic	Tests	No of Students	Mean	Pooled Std Dev	t-value	p-value
Topic 1	Pre-test	77	56.48	35.5	3.12	0.0011
	Post Test	77	74.31			
Topic 2	Pre-test	74	49.04	28.2	3.10	0.0012
	Post Test	74	63.52			

The survey showed that learners had a positive experience with adaptive learning, finding it useful and easy to use. Over 95% agreed personalised learning helps them understand concepts and apply them. They feel that this approach makes learning simpler, easier to understand and more appealing. The learners appreciate the immediate feedback that the adaptive tool provides, which helps them identify their knowledge gaps and reinforce their learning independently. Additionally, the ability to focus on the most effective material for each learner per learning objective allows them to clarify any uncertainty and build their confidence in their understanding of the material. As a result, the learners felt more confident and motivated to keep on their learning journey. More than 80% of the learners preferred individualised learning paths and focused remediation over the traditional one-size-fits-all approach. Despite the limited scope of this study, which only piloted two topics, the learners involved expressed a desire for adaptive learning to be extended to cover more topics. This feedback suggests that adaptive learning can be a valuable and effective tool for enhancing the learning experience. The results of this research provide evidence that supports the use of adaptive learning in education.

Figure 6 Survey results

Figure 7 Word cloud on how the learners feel about adaptive learning

Another important aspect of adaptive learning is data analysis. This involves using the data from learner performance and interactions with the system to identify patterns and trends. This information can then be used to adjust the learning for individual learners, or to identify areas where the curriculum needs to be improved.

Adaptive learning also offers advantages from the teacher's perspective. By generating learning analytics, Brightspace provides valuable feedback that allows teachers to make decisions about their teaching strategies. Brightspace provides teachers with an activity report that displays the viewer rate of each learning objective. A higher viewer rate for a specific learning objective suggests that most learners may be finding that learning objective challenging and may benefit from additional support or clarification. The teacher can then allocate more time during face-to-face lessons to clarify these concepts.

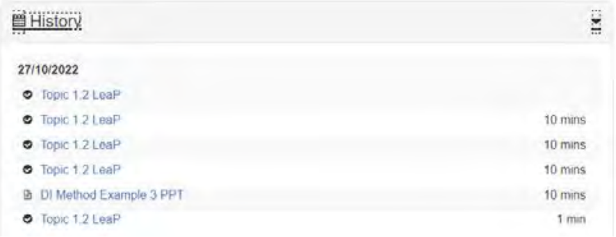
Learning Objective	Path Viewed	Supplemental Viewed	Recommend Reading Views	Question Remediation Views	Time On Page	Last Accessed
[illegible]	215	41	2	32	1:17:19:58	11/6/2022 5:18:19 AM
[illegible]	78	19	7	21	16:28:45	11/6/2022 4:34:18 AM
View all Activity for "Topic 1.1 LeaP 2"	288	60	9	53	2:09:48:43	11/6/2022 5:18:19 AM

Figure 8 Activity Report

Brightspace also provides teachers with detailed information on individual learners' progress towards the learning objectives, enabling them to track each learner's performance and monitor the materials they have accessed. By identifying learners who have not made sufficient progress, teachers can provide targeted interventions and support, enabling them to achieve better learning outcomes. For example, teachers could arrange for struggling learners to attend peer tutoring or face-to-face supplementary lessons that target specific areas of difficulty. By leveraging the data generated by Brightspace, teachers can take proactive measures to help these students achieve their learning goals.

Progress for NG XU [redacted] STU-SEG

Figure 9 Learner's Progress Report



History

27/10/2022

Topic 1.2 LeaP	
Topic 1.2 LeaP	10 mins
Topic 1.2 LeaP	10 mins
Topic 1.2 LeaP	10 mins
DI Method Example 3 PPT	10 mins
Topic 1.2 LeaP	1 min

Figure 10 Learner's Viewing History

Additionally, Brightspace's ability to filter data by class allows teachers to identify the class learning profile and customise their classroom management techniques to better support their learners.

Conclusions

Adaptive learning benefits both learners and educators. It helps learners by improving their understanding of the material, increasing their engagement, and improving overall performance. It is time-efficient as learners only focus on what they don't know, skipping the learning objectives they already attained. Both statistical improvements in the scores and the survey results suggest that adaptive learning is preferred over the traditional one-size-fits-all approach. For educators, adaptive learning helps to improve teaching effectiveness and identify areas where the curriculum needs improvement. Adaptive learning is well-received by both learners and educators and can be used in most courses. Adaptive learning is a powerful learner-centric tool that revolutionizes the teaching and learning experience. With encouraging results from this investigation, educators are encouraged to use adaptive learning to support learning.

Acknowledgements

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A REPORT ON OPEN COURSES IN FINANCE FOR CITIZENS, TAUGHT BY FEMALE STUDENTS (RIKEJO) AT NIT, KURUME COLLEGE

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Abstract

In Japan, it has been said that, in the past, there were few opportunities for children to learn financial literacy. In reference to this, the country's surrounding environment has been changing: low interest rates, the spread of the Internet, and the lower age of adulthood. Then, in 2022, financial education was introduced to high schools. However, in the age of Society 5.0—the concept of a future society advocated by the Japanese government—there is a need for human resources with the skills to grasp things from multiple perspectives and solve problems, referred to as STEAM human resources. (STEAM is an abbreviation of science, technology, engineering, (liberal) art and mathematics.) Since 2019, we have practiced STEAM education in the "Liberal Arts Special Lecture" with the 4th-year students at the National Institute of Technology, Kurume College (Kurume KOSEN). In the lecture, teachers give themes related to their own expertise. Through collaborative learning between students from various departments, we have led those students in integrating knowledge and creation so as to achieve deep learning. We have formulated financial teaching material on simple interest and compound interest from the perspective of STEAM education, i.e., a fusion of economics and mathematics. Moreover, we have used this material in an open course for citizens by utilizing the abilities of liberal arts special course students and the 3rd-year students who studied both subjects as instructors. In addition, we have selected female science students (RIKEJO) to serve as the instructors of this course, since we are informed that RIKEJO are studying in KOSEN. As a result, we have been highly rated by the participants and the female students have had a good opportunity to give back their acquired knowledge and ability to society. This initiative has just begun, and so we must continue to develop education methods. In the current report, we propose financial teaching material which is relevant to economics and mathematics, while we also review the open course.

Keywords: *financial education, simple interest and compound interest, STEAM education, economics, mathematics*

Introduction

Introduced by Georgette Yakman, STEAM education is an approach to learning that uses science, technology, engineering, the arts, and mathematics as access points to guide student inquiry, dialogue, and critical thinking in order to solve problems in the real world.

The main purpose of this work is to create financial education material regarding simple and compound interest for citizens from the perspective of STEAM education by utilizing the abilities of RIKEJO (female science students) as teachers.

We have studied mathematics education of and put it into practice in many different places (e.g., M. Sakai and T. Tanaka, 2014; K. Kawashima, M. Sakai, Y. Matsuda, 2021). We also taught mathematics with our students on many open courses for junior high school students (e.g., M. Sakai & T. Miyaji 2013；M. Sakai, T. Miyaji and S. Nakabo 2013; K. Kawashima, Y. Matsuda, M. Okita, M. Sakai, and T. Tanaka, 2018).

In this paper, we report on our practice of STEAM education for citizens. We formulated financial teaching materials as a fusion of economics and mathematics.
In this practice, our female students acted as teachers and used these teaching materials.

This article is organized as follows. The structure of open course describes the construction of open courses. In some scenes of open course, we review scenes from an open course using photographs. In economics and mathematics, we introduce the open course in economics and mathematics. Results of the questionnaire describes the results of the questionnaires administered to participants. Finally, conclusion of this effort and a future subject presents conclusions and future challenges.

The structure of open course

We constructed the open course in economics and mathematics as follows:

(a) Learning content
Simple and compound interest viewed from the perspective of economics and mathematics.

(b) Construction
- Participants: Seven citizens
- Leaders: Three female students as teachers and two teachers as facilitators
- Time: 120 minutes (60 minutes for economics and 60 minutes for mathematics)

Some scenes of open course

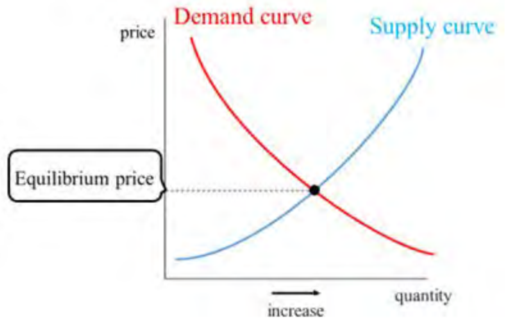
In this section, we review scenes from the open course with photos. Female students showed slides on the screen (Figure 1) and explained some points for solving problems involving simple and compound interest. Participants took notes on their answer sheets before solving the problems while female students walked around and answered their questions (Figure 2). Through these activities, female students developed their ability to teach others.

[Figure 1: Lecture]

[Figure 2: question answering by a female student]

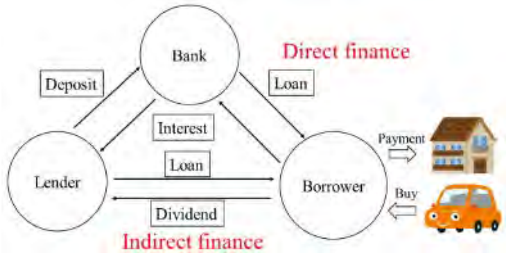
Economics

In the economics section, female students specializing in economics (liberal arts) provided explanations on such subjects as economics, household finances, finance, and debt. In the introduction to economics, participants were asked to give examples of economic reports in daily news stories that aroused their interest. In the lecture, economic activities were defined as human production and consumption activities and various activities derived from them (e.g., finance). In the case of household finances, the relationship between supply and demand in the market was explained using graphs after explaining the purposes of companies and households (Figure 3).



[Figure 3: Relation between demand and supply]

We explain direct and indirect financing using diagrams (Figure 4).

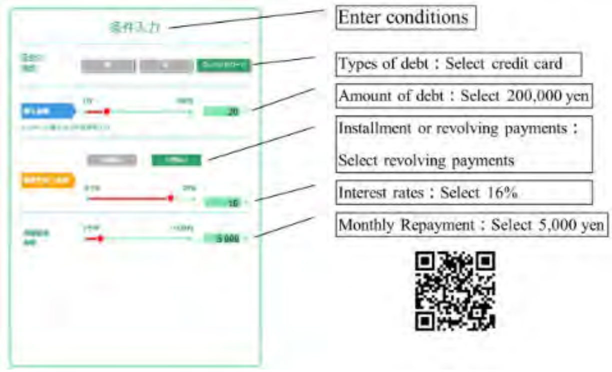


[Figure 4: Relation between direct and indirect finance]

Regarding debt, questions were given in the form of a quiz, as shown below, and the answers were provided using a simulator (Figure 5).

[Table 1: Exercise 1.]

Exercise 1.
I borrowed 200,000 yen at a 16% interest rate because I am going on an overseas trip with my friends. If I repay 5,000 yen per month, how many years will it take to repay and how much will I pay back in total? (Choose from (1) to (3), below):
(1) one year, 210,000 yen
(2) three years, 250,000 yen
(3) five years, 290,000 yen



Enter conditions

Types of debt : Select credit card

Amount of debt : Select 200,000 yen

Installment or revolving payments : Select revolving payments

Interest rates : Select 16%

Monthly Repayment : Select 5,000 yen

[Figure 5: Debt simulator]

Mathematics

In the math section, a female student taking the responsible author's math class explained simple and compound interest, how to save and pay back money, and the power of long-term accumulation and compound interest. For simple and compound interest, the differences and calculation methods were explained. Students used their calculators to solve a problem exercise 2 in which these differences were confirmed (Figures 6 and 7).

[Figure 6: Explanation of simple and compound interest**]**

x years later	1	2	3	5	6	7	8	9	10
simple interest									
compound interest									

How to calculate by calculator	
$100×1.03^2$	100×1.03 = =
$100×1.03^3$	100×1.03 = = =
$100×1.03^4$	100×1.03 = = = =

[Figure 7: Calculation of simple and compound interest]

[Table 2: Exercise 2]

Exercise 2.
Use a calculator to calculate simple and compound interest when investing 1 million yen at an annual interest rate of 3%.

In the question regarding how to save money and return it, we posed the problem of using a simulator to calculate how saving and returning one million yen would change when the amount of money saved, and the interest rate changed (Exercises 3 and 4).

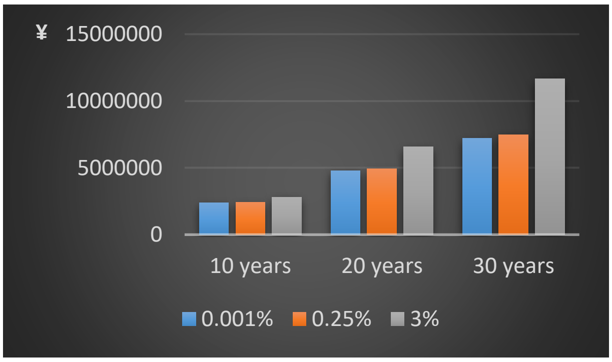
[Table 3: Exercise 3]

Exercise 3.
Determine how much you can save over 10, 20, and 30 years of compounded interest, assuming a monthly reserve of 20,000 yen and annual rates of 0.001%, 0.2%, and 3%.

[Table 4: Exercise 4]

Exercise 4.
I borrowed 1 million yen at an annual interest rate of 5%.
(1) If I return 100,000 yen at the end of each year, how many years will it take to repay it?
(2) If I return 40,000 yen at the end of each year, how many years will it take to repay it?

In terms of the power of long-term accumulation and compound interest, we used a graph to illustrate the comparison of the total amount of 20,000 yen when the period of accumulation and interest rate changed (Figure 8).



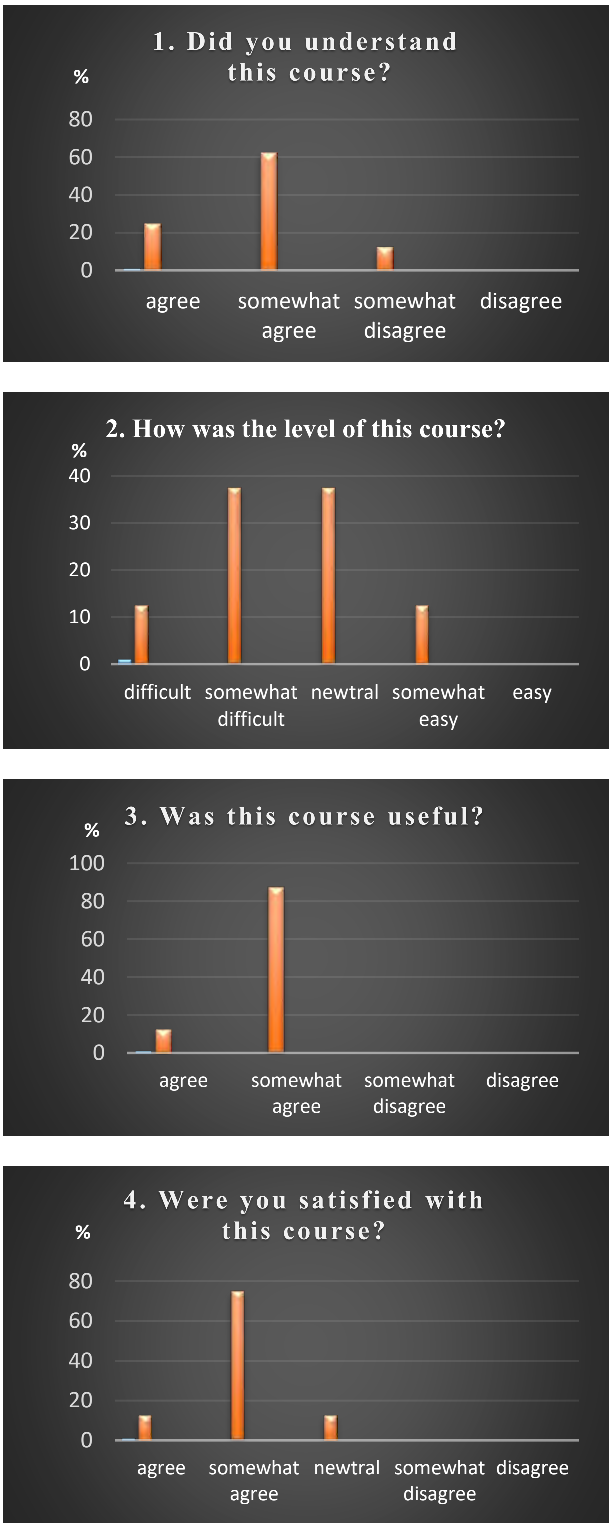
[Figure 8: Saving period and interest rates]

Results of the questionnaire

We administered a questionnaire to the participants concerning the above themes. The questions and their results follow:

[Table 5: Questionnaire for the participants]

Question 1. Did you understand this course?
Question 2. How was the level of this course?
Question 3. Was this course useful for you?
Question 4. Were you satisfied with this course?



[Figure 9: Answer from the participants]

The results of Questions 1 and 2 indicated that the participants understood the content of the lecture even though it was not elementary. One reason is that the lecture focused on ways to compute curvature instead of strictly theoretical arguments.

Since participants were familiar with a quadratic curve in daily life, many answered Question 3 positively. As indicated by the responses to Question 4, more than 80% of the participants were satisfied with the open course.

We received the following comments about our theme and teaching materials from participants:

[Table 6: Comments from participants]

"In the economics part, I wanted more specific examples. In the math part, the actual numerical calculations made me realize that the impact of interest rates is significant. Overall, I am glad I attended the course."
"The female students' explanations were calm and good."
"It was interesting but disappointing in that there were so few participants."
"I will try the simulation at home. I found the course very useful. I wish more people had listened to it."

Conclusion of this effort and a future subject

We received the following comments about our theme and teaching materials from female students:

[Table 8: Comments from female students]

"I was nervous, but it was a good experience."
"I thought it was useful and easily understood the results of the savings using simulations."
"I should have practiced the simulation a little more. I am glad to have learned about interest rates through this course. I would like to make use of it when I borrow money in the future."

The questionnaire demonstrated that our course was effective for learners and showed potential as a STEAM teaching tool.

Here, we describe two teaching tools for future use. One is knot theory, which is easily understood by beginners because it is not necessary to be familiar with its background. Additionally, various teaching materials promote visual learning. Knot theory is associated with various fields, such as the quantum field theory in physics, molecular design in chemistry, and DNA biology. In the future, we intend to create STEAM teaching materials related to physics and chemistry. K. Kawashima, M. Sakai. and T. Tanaka (2014), K. Kawashima, M. Sakai, T. Tanaka. & Y. Matsuda (2015), and M. Sakai, T. Tanaka (2023) studied teaching with knot theory and used it to guide learners to deeper learning. We will develop teaching materials on knot theory from the perspective of STEAM education.

The second tool is graph theory, an interesting field of study. It is easily understood by beginners because familiarity with the background is unnecessary. Graph theory is associated with various fields, such as physics and chemistry, computer science, linguistics, and the social sciences.

Acknowledgements

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Writing Education to Enhance the Self-Expression Ability of Technical College Students: A Report on the Practice of Fukushima Kosen

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Abstract

In the department of Japanese (a part of General Education), National Institute of Technology, Fukushima College (Fukushima Kosen), continuous writing education is provided to students in the four engineering departments. In the 2nd year, an essay contest is held to cultivate the basis for persuasively communicating one's opinions based on written materials; in the 3rd year, students write summaries and opinion essays in the Japanese class to mutually improve reading comprehension and expression skills; in the 4th year, the course of "Japanese Expression Methods" is offered to develop practical expression skills for employment and higher education. This paper describes the approach to writing education at Fukushima Kosen, and analyzes its achievements and challenges based on the results of a questionnaire survey of students. At the same time, the possibility of teaching writing with digital devices will be discussed by adding an explanation of online class initiatives in the Corona Disaster, based on the results of a survey of students. This will provide a solution to the pressing issue of what kind of writing skills are necessary in engineering education and how they can be developed. Today, there is a need to produce many engineers with advanced expertise, and it is necessary to train individuals who can communicate with others and collaboratively work on issues. For this purpose, it is important to have the skills to persuasively convey one's ideas to others. The continuous writing education at Fukushima National College of Technology has been successful in fostering such human resources.

Keywords: *Writing education, Self-expression ability, Essay contest, Writing a summary, Guidance for employment and higher education*

Introduction

National Institute of Technology, Fukushima College (Fukushima Kosen) has five departments (Mechanical Systems Engineering, Electrical and Electronic Systems Engineering, Applied Chemistry and Biochemistry, Civil and Environmental Engineering, and Business Communication). The department of Japanese has long provided students in the four engineering departments (excluding the business communication department) with training in the ability to express themselves in writing. The following section describes the status of the program and presents the results of a questionnaire survey of students to confirm the degree to which the program has achieved its objectives. By investigating the degree to which students are satisfied with the writing skills that the department of Japanese considers necessary for students and their educational practices, as well as the difficulties they are experiencing. By doing so, we hope to provide an answer to the question of how the writing skills required of students in engineering higher education can be developed.

Abilities to be developed in Japanese classes in Kosen

Fukushima Kosen has revised its college-wide curriculum several times. Traditionally, the department of Japanese has emphasized literature education and has long offered a "literature" class for 4th-year students. This is because we believed that a career as an engineer requires an education in the humanities as well. However, what students demanded of their Japanese teachers was not a liberal arts education in literature. As the spring of their 5th year approached, when preparations for job hunting and university transfer examinations were in full swing, students visited Japanese teachers individually, eagerly requesting corrections to their resumes and entry sheets to be submitted to companies and their statements of purpose to be submitted to transfer universities. The Japanese teachers responded to the students' individual requests, but providing individualized instruction in written expression outside of regular classes was a significant burden, taking into account the number of instructors (three) and school duties. In order to respond to the students' solid need to improve their writing expression skills, we tried out a class for students to create summary sentences in the 3rd grade "Japanese" class (Takahashi has had students write 100-word summary sentences in class since 2007), but it remained an individualized effort by the teachers. Since there was a limit to improving students' ability to express themselves, measures were discussed within the department of Japanese, and on the occasion of the curriculum revision, it was decided to abolish the 4th-year "Literature" class and establish a new "Japanese Composition" class to improve practical writing skills, and the class has been offered since 2018. In line with this, it was decided to conduct summary writing exercises in the 3rd-year "Japanese" class in all four engineering departments.

In addition, at the direction of former principal Osamu Yamashita, who strongly believes that technical college students need to strengthen their ability to express themselves in writing, an "essay contest" has been held since 2021 for 2nd-year students in the main course, and all 2nd-year students are required to write an 800-word essay.

The Organization of National Institute of Technology has formulated a model core curriculum "to produce human resources who will be active in society and industry in the future," and is implementing education that introduces this curriculum for all students enrolled in 2018 and later[1]. In the Model Core Curriculum established in April 2023, the subject "Japanese" is defined as follows: "'Japanese' is designed to provide students with the linguistic and cultural literacy that forms the foundation of humanity, and to enable them to understand diverse others in depth by practicing effective and interactive communication on their own initiative. By doing so, we aim to improve their linguistic ability to flexibly respond to changing situations and their operational ability of Japanese language related to their field of specialization". It also states, "In order to improve language skills, it is important to link 'Japanese' with subjects other than 'Japanese'" (The Organization of National Institute of Technology, 2023: 48). The Model Core Curriculum also requires the bridge between "Japanese", which is positioned in the "MCC (Core)" as a basic ability that engineers should possess, and "communication skills", which is positioned in the "MCC (Model)" as a basic quality that should be demanded by the entire university (The Organization of National Institute of Technology, 2023: 10-13).

In light of this situation, various attempts have been made and reported on the organization of the Japanese language curriculum at each Kosen (e.g., Miyamoto, 2010; Miyamoto, 2013). Some of them have organized Japanese classes in a way that links them with career education (e.g., Kusano, 2011; Kusano, 2016; Kusano, 2018). Among these, the Japanese classes that require "communicative competence" focus mainly on the cultivation of communicative competence through oral presentations and discussions, and to date, there have been continuous reports of presentations and group discussions in Japanese language classes (e.g., Funato, 2004; Aikawa, 2012; Narumi, 2019). In other words, the current efforts of Japanese courses in Kosens with an emphasis on the ability to express oneself in writing are still insufficient, and reporting and evaluating the efforts of the Japanese courses in Fukushima Kosen will be helpful to consider how to improve the ability to express oneself in writing in future education at technical colleges.

Writing education by the department of Japanese in Fukushima Kosen

In this section, we report on the writing education for improving written expression skills provided by the department of Japanese in Fukushima Kosen to students in four engineering departments.

As mentioned in the previous section, before 2018, despite the needs of students at Fukushima Kosen to be taught how to write resumes and entry sheets to be submitted to companies or motivation letters to be submitted to universities in preparation for job hunting or transferring, or to better complete the documents to be submitted, there were no classes that responded to this need. Teachers also wanted to teach students to improve their ability to express themselves in writing and to enable students to write at the level demanded by society, but they were not sure how to do this within the existing curriculum. In order to resolve the discrepancy between the needs of students and the wishes of faculty members, we examined the abilities that students should acquire during their five years at the time of college-wide curriculum revision, and while referring to the curricula of other colleges, we came up with educational contents to improve reading comprehension and writing expression skills within a limited number of credits, which were then incorporated into the syllabus. **Figure 1** shows the curriculum of Japanese that started in 2015[2].

Figure 1: Curriculum of Japanese class in Fukushima Kosen and the status of implementation of the teaching of written expression

In the 1st-year "Japanese" course, students are required to acquire basic reading comprehension skills for modern, ancient, and Chinese texts using a high school textbook (cf. Tsubouchi, 2019a; Tsubouchi 2019b). In addition, students are required to purchase workbooks corresponding to levels 3 to 2 of Jyouyo

Kanji, and are given regular Kanji tests. In the 2nd-year "Japanese" course, students are required to read and comprehend modern, ancient, and Chinese texts using the approved textbook for modern Japanese B (cf. Tsubouchi 2020), as they did in the previous year. Kanji tests will also be given on an ongoing basis. 1st and 2nd-year classes will be given to acquire basic knowledge (Kanji, words, and phrases) and prerequisite skills (reading comprehension to enhance logical thinking) for writing. These knowledge and abilities are aimed to be established through periodic examinations and Kanji tests.

Starting in 2021, an "essay contest" was held for 2nd-year students, requiring them to write an 800-word essay as a summer assignment[3]. All students are required to submit the essay, and awards are given for outstanding essays. Each essay must cite sources. However, since students have no experience in writing essays, we instruct students on how to write essays and how to search for materials in class before the summer vacation, and take students to the library.

In the 3rd-year "Japanese" course, students continue to practice writing summaries in class to improve their reading comprehension and writing expression skills. In Takahashi's class, the texts discussed in one unit are divided into paragraphs, and after Takahashi gives a brief explanation of the contents of the paragraphs, students summarize the contents of the paragraphs in 100 words or less and submit the summary on a handout prepared by Takahashi. In 2022, 21 summary assignments were given throughout the year. 3 full-time and 1 part-time instructors, including Takahashi, were in charge of all 3rd-year classes in 2022, and every class had a summary exercise[4].

The 4th-year "Japanese Composition" course aims to complete the students' ability to express themselves in writing. After practicing questions on the basics of written expression, such as idiomatic expressions or honorific expressions, using the textbook (cf. Yoneda 2010), students write letters, guides, resumes and entry sheets for job hunting, and statements of purpose for transfer schools, according to the contents of the textbook. In particular, job applicants are expected to complete their drafts in class and leave only a clean copy, in light of the current situation where employment is being hastened. These are submitted as assignments and returned with corrections or comments.

Details of the above classes are available on the web syllabus of Kosen[5].

Confirmation of achievement through student surveys

In order to confirm how well the efforts of the department of Japanese in Fukushima Kosen are meeting the needs of students, and to explore new needs on the part of students to help improve future classes, a questionnaire including the following items regarding classes was sent to 3rd to 5th-year students in the main course.

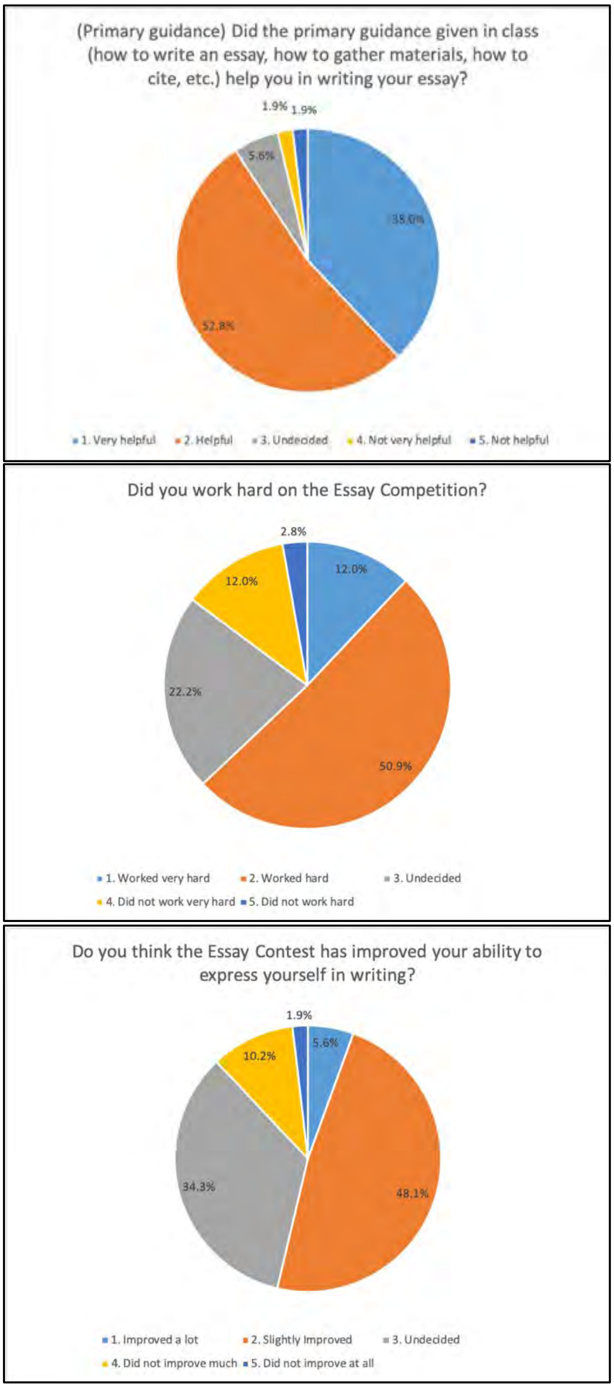
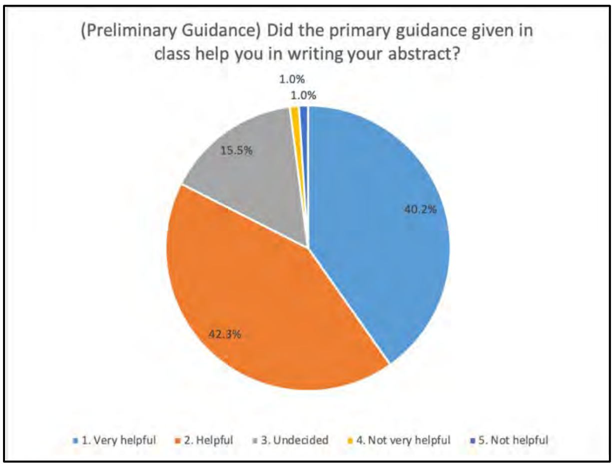
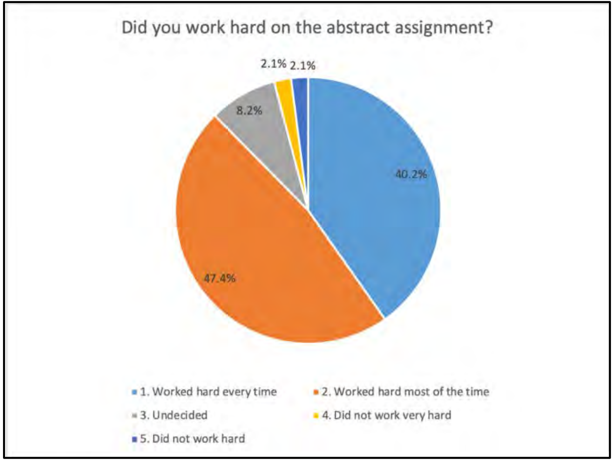


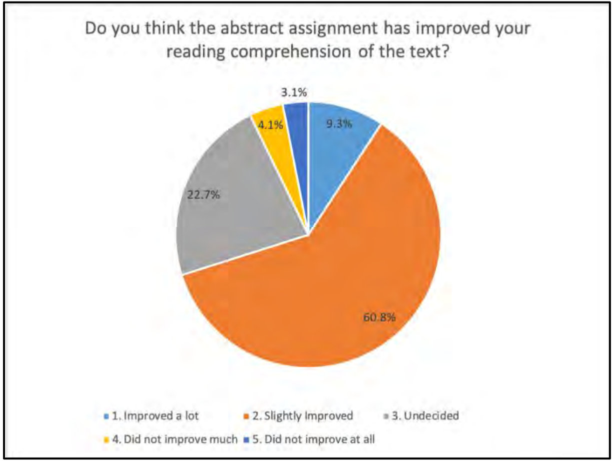
Figure 2: Results of a questionnaire about the essay contest for 3rd-year students

There were 162 3rd-year students enrolled in the four engineering departments, with 108 responses (66.7% response rate).

79.6% of the students understood the purpose of the essay contest, and 90.7% found the preliminary guidance helpful. On the other hand, 63.0% of the students answered that they worked hard, and only 53.7% of the students felt that the competition improved their ability to express themselves in writing. In the questionnaire, students were asked in a descriptive form about "difficulties in writing essays," and the most common response (27 responses) was that they had difficulty in obtaining and citing materials. Considering that 18 respondents felt difficulty in the composition and expression of sentences, it can be said that the task of writing their ideas based on materials was more difficult for the 2nd-year students than the instructors had expected. Although the program was initiated with the strong enthusiasm of the principal at the time, it did not receive the college-wide support requested by the department of Japanese, and the inadequate preparation of the students for the summer vacation assignment was exposed. In order to continue the program in the future, it is necessary to reexamine the grades in which the program was conducted, and to devise new methods of prior guidance and correction.







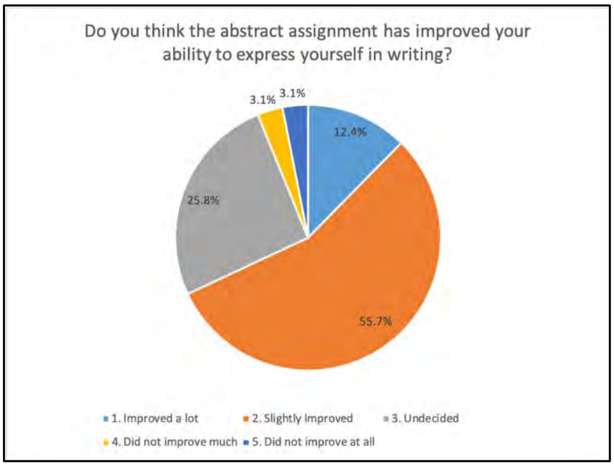
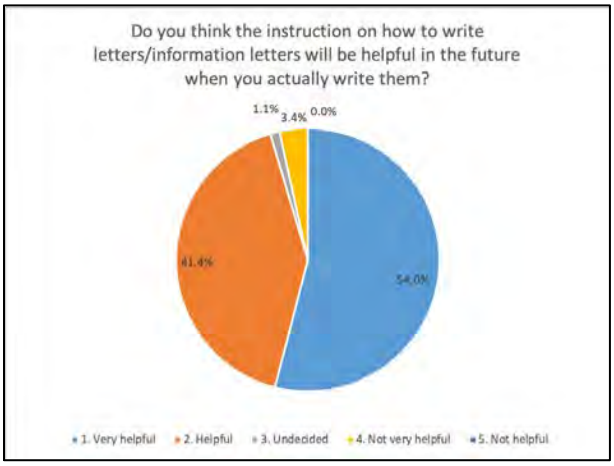


Figure 3: Results of a questionnaire about summary writing exercises for 4th-year students

There were 165 4th-year students enrolled in the four engineering departments, with 97 responses (58.8% response rate).

75.3% understood the purpose of the summary writing exercise, 82.5% found the advanced instruction helpful, 87.6% worked hard on the summary writing exercise, 70.1% felt that it improved their reading comprehension, and 68.0% felt that it improved their ability to express themselves in writing. The summary writing exercises have been conducted in Takahashi's classes since 2007, and for the last five years, other teachers have also adopted similar exercises, but both teachers and students have become accustomed to the exercises and feel that the results are positive.



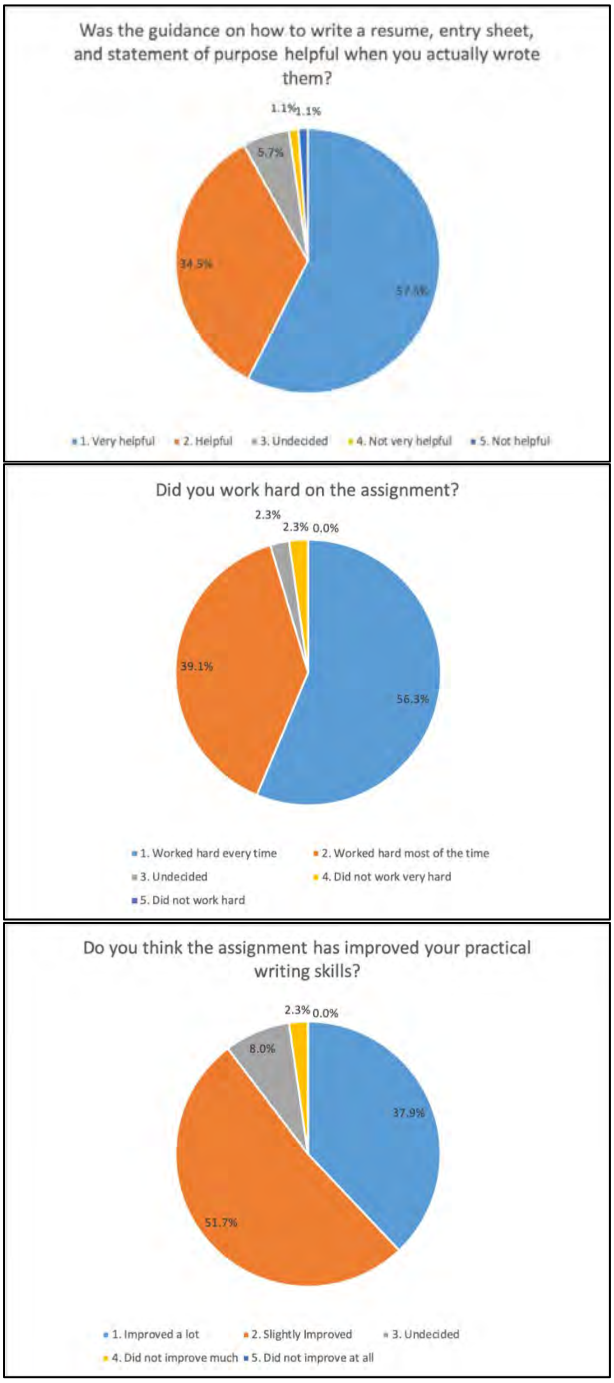


Figure 4: Results of a questionnaire about "Japanese Composition" for 5th-year students

There were 158 5th-year students enrolled in the four engineering departments, with 87 responses (55.1% response rate).

95.4% understood the purpose of the class. The purpose of offering the class in the 2nd semester of the 4th year is to prepare students for employment and higher education in the class and to raise their awareness of their career paths, and as the instructors aim, a high percentage of the student work hard about the assignments (writing letters, information letters, resumes/entry sheets, and statements of purpose). The percentage of students who worked hard on their assignments (writing letters, guides, resumes, entry sheets, and personal statements) was as high as 95.4%. More than 90% of the students found the class content and exercises helpful, and 89.7% of the students thought that their practical writing skills had improved.

Conclusions

The student survey results indicate that students understand the objectives of the 3rd-year "Japanese" and 4th-year "Japanese Composition", are highly motivated to learn, and feel that their ability to express themselves in writing is improving. The needs of the students and the teachers' awareness of the issues matched, and after thorough consideration and preparation within the department of Japanese, they were introduced into the curriculum, which can be evaluated as having achieved the expected results. On the other hand, the essay contest did not reach the expected level in terms of students' motivation to learn and their sense of achievement, and the results indicated the need to reconsider the contest, including whether or not it should be held. Many students in the 3rd and 4th-year classes, where assignments are corrected and returned to students, have seen improvement in their ability to express themselves in writing. The fact that it is difficult to improve writing expression skills in a competition format without correction was brought to light.

A 4th-year student wrote the following opinion in the free writing section of the questionnaire: "I think there is a tendency that writing reports is something you have to learn by yourself. I did not know what kind of writing I should do for my report in the 1st year of Kosen. It is in the 3rd year of Kosen that the rules and basics of writing are finally taught in "Japanese" and "Seminar in Humanities and Social Sciences I". [...] I think that until the 3rd year of Kosen, there is a reality that students write reports and so on without knowing anything about writing. The teachers in each department do not have the opportunity to teach students how to write in class". That student's statement indicates the high demand for education in written expression, including report writing, and for a college-wide five-year curriculum to realize this demand. In order to improve the ability to express oneself in writing in a broad sense, including writing class reports, it is necessary to set an achievable goal of what ability to develop and when and how to develop it. To achieve this, it is desirable to organize a five-year integrated program on a college-wide basis, and then each department should implement the program by incorporating it into classes within their respective areas of responsibility, and indeed, students are hoping for this. It is probably from this awareness of the issue that the new model core curriculum describes strengthening cooperation between "Japanese" and subjects other than "Japanese".

We propose the following suggestions as measures to resolve these issues. First, the entire college should share an awareness of the issues related to writing expression education and provide programs that meet the needs of students from an early stage. Specifically, guidance for the improvement of writing expression skills, or the establishment of new subjects to be jointly taught by Japanese teachers and other teachers may be considered.

Second, in the department of Japanese, it is necessary to organize a curriculum for the improvement of writing expression skills in a five-year plan, with a view to a college-wide initiative. Third, in addition to classroom instruction, it is necessary to establish a system that enables not only Japanese teachers but also departmental or college-wide backup for individual instruction to respond to students' needs.

We would like to add a comment on the impact of covid-19 on writing education at Fukushima Kosen. Covid-19 has made the submission, correction, and return of assignments more efficient through the digitization of assignment submissions using Microsoft Teams. Also, the fact that this has become the standard today is a benefit in the current situation where personalized education must be provided with fewer staff members. The digitalization brought about by Covid-19 has both set the foundation and made efficient the five-year writing education. The outcomes and challenges of the digitalization of written expression education are issues that should continue to be discussed.

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[1] The Organization of National Institute of Technology explains the "Model Core Curriculum" at the following web page (https://www.kosen-k.go.jp/about/profile/main_super_kosen.html).

[2] The curriculum has since been newly revised, and the number of credits for "Japanese" offered in the 1st and 2nd years of the four engineering departments has been reduced to 2 credits, starting with students entering in 2022.

[3] The 2021 assignment was "What I can do to realize the SDGs," and the 2022 assignment was "What kind of liberal arts is necessary for engineers?". The submitted essays were read by the Japanese teachers, and one Grand Prize winner, two Excellence Award winners, and two Encouragement Award winners were selected and awarded at the closing ceremony.

[4] Before covid-19, all assignments were required to be submitted in paper form, but after covid-19, the format has shifted to requiring the submission of image data using Microsoft Teams. Today, data submissions have become the standard, contributing to increased efficiency in submitting, correcting, and returning assignments.

[5] The Organization of National Institute of Technology releases the syllabus at the following web page (https://syllabus.kosen-k.go.jp/Pages/PublicDepartments?school_id=10&lang=en).

Cyber Security Education Practice in Credit Transfer System among National Institutes of Technology

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Abstract

Cybersecurity education in engineering education is becoming increasingly important, and the cybersecurity human resource development project that began at KOSEN in 2015 has entered its mature phase. The author has been responsible for the practical technical aspects of this project and has developed many cyber security educational materials. Lectures using the developed educational materials have been practiced and educational effectiveness has been measured. The relationship between educational effectiveness and motivation has also been examined, and the latest research results show that a high educational effectiveness can be expected if the motivation score of the students in the course is 4 or higher (on a scale of 1 to 5 points). In 2022, KOSEN started a credit transfer system among national institutes of technology, and National Institute of Technology, Kisarazu College, which is the base college of this project, offered "Information Security Exercise," which is the author's subject and enables students to learn about vulnerabilities in web applications through practical exercises. Thirty-seven students from National Institute of Technologies across Japan received credits for the course. In light of previous research results, the 37 students were classified into two groups according to their motivation scores on a pre-course questionnaire: the ultra-high motivation group (mean: 4.48) and the high motivation group (mean: 4.00) (analysis of variance showed a significant difference in mean scores (F(1,35)=11.37, p <.005)). Students' scores on cybersecurity skills and knowledge (operational and construction, knowledge and law, certification, vulnerability, and defense in depth) were obtained by questionnaire before and after the course. Analysis of variance showed that both the highly motivated group (Fs(1,100)>=10.65, ps<.005) and the ultra-highly motivated group (Fs(1,75)>=17.20, ps<.001) showed significant score increases on all five items. To examine consistency with the learning content, we also analyzed the magnitude of score increase for the five items and found a significant difference between the magnitude of score increase for vulnerability and the other items (ts(140)>=3.705, ps<.0003). These results confirm that the assumed skill improvement was appropriately practiced, and replicate that a motivation score of 4 or higher is highly effective for learning. To effectively utilize these results in other subjects, it is important to set goals based on appropriate historical background and to prepare prior learning to further increase interest.

Keywords: *Credit Transfer System among National Institutes of Technology, Cyber Security Education Practice, Motivation, Information Security Exercise*

Introduction

As cyber-attacks intensify, cyber security education is becoming increasingly important in engineering education around the world; KOSEN education, which emphasizes the acquisition of practical skills from the age of 15, fits well with Cybersecurity Body of Knowledge (CyBoK) advocated by Awais et al. (2018), who also advocate the importance of the technical aspects. Therefore, KOSEN became a target of national policy support, and the Cyber Security Human Resource Development Project (K-SEC) was initiated at KOSEN in 2015, and a faculty development project was launched within the project in 2019, with Kisarazu National College of Technology in charge of the project. The reason for launching the faculty development project is simple: if faculty members become stronger, students will also become stronger. In this project, practical training was conducted to improve the skills of faculty and staff, and the experience was used to develop teaching materials to foster students with a high skill level.

In 2022, K-SEC will be reborn as a cyber security field in COMPASS 5.0, a part of the "Society 5.0 Future Technology Human Resource Development Project" that KOSEN has started since 2020, and is expected to be further deepened and developed. Kisarazu National College of Technology has been a base school supporting Kochi National College of Technology, the core school of K-SEC, from the time K-SEC was established, but in COMPASS 5.0, it has become a full base school along with Kochi National College of Technology. The author has played a central role in the practical technical aspects of this human resource development project and has developed many cyber security educational materials together with the project team members. The author has also implemented the developed educational materials in lectures at his own college of technology, and has measured their educational effects. In addition, he has examined the relationship between educational effectiveness and motivation, and his latest results show that a motivation score of 4 or higher (on a scale of 1 to 5) for students can be expected to have high educational effectiveness (e.g., Yonemura et al., 2023).

In the same year of 2022, KOSEN started a credit transfer system among national colleges of technology, and Kisarazu National College of Technology, which serves as a base school for the cyber security human resource development project, began offering the author's course, Information Security Exercise. The Information Security Exercise is an introductory course to learn about vulnerabilities of web applications through practical exercises in a wide range of cyber security fields. Many technical college students from all over Japan had the opportunity to apply for the course, and in the end, 37 students received credits.

This paper describes the outline and practical methods of the Information Security Exercise, a course related to the Cyber Security Human Resource Development Project, which is a new trial for KOSEN and is expected to be challenging, and the effects obtained by the participants. The lecture will also include a discussion on the relationship with the motivation of the participants. The degree of skill improvement on vulnerability in the cyber security field learning items (defined as a total of 5 items), which was the goal of the project, was higher than the other 4 items. The high effectiveness of the priority items while obtaining considerable educational effects from the high level of motivation was demonstrated, which also led to confirmation of the validity of the content of the practical exercises. The findings have the potential to be applied not only to KOSEN education and education in the field of cybersecurity, but also to engineering education in higher education institutions more broadly, contributing to the advancement of engineering education as a whole in a lasting manner.

Materials and Methods

The lecture "Information Security Exercise" in the credit transfer system for national colleges of technology in FY2022 was held in the second semester, specifically from October 2022 to February 2023. The materials were distributed by Microsoft Teams. Seventy students from all over Japan wished to take the course, regardless of their departmental grade. In the end, 37 students earned credits. No timetable was set; materials were added once a week, and each student worked on the lectures and exercises in his/her own free time. Questions were asked using individual chats, and content that needed to be made available to all participants was posted in the form of messages on Teams and made available to all.

The themes of the lecture materials were as follows:

- Construction of a target server to learn about vulnerabilities in web applications
- SQL injection attacks and defense exercises
- Directory traversal attacks and defense exercises
- Attacks and defense exercises for OS command injection
- Bind Shell and Reverse Shell
- Final assignment in the form of Capture the flag

Each participant prepared a virtual machine on his/her own PC, installed an OS, and built a target server. Then, in a closed network environment within the PC, the attacker's PC connected to the target server was also prepared as a virtual machine, and an attack defense exercise against web application vulnerabilities was conducted. The skills and knowledge acquired through the lectures were used for the final exam, Capture the flag.

In measuring the effectiveness of the education of students, which has been promoted as part of the cyber security human resource development project to date, skill check questionnaires on skills and knowledge in the field of cyber security have been conducted before and after attending lectures using the developed teaching materials (e.g., Yonemura et al., 2022; Yonemura et al., 2021) Furthermore, in the process of conducting educational effectiveness measurement research, we have conducted a study examining the relationship between motivation and educational effectiveness (e.g., Yonemura et al., 2023). In this study, we followed the above format that we have promoted in the past and had the participants answer the same skill-check questionnaire and motivation questions before and after the course. Responses were based on self-assessment.

The skill check questionnaire included items for monitoring and discussing the growth of skills before and after the course. The items were set by the steering members based on the knowledge system SecBOK by Uehara et al. (2019) and the experience of cybersecurity training (e.g., MIC, 2016) in which the steering members of the faculty development project participated (e.g., Yonemura et al., 2023; Yonemura et al., 2022; Yonemura et al., 2021).

Scores are on a 5-point scale from 1 to 5, based on respondents' self-assessment: 1 is "not knowledgeable," 2 is "knows," 3 is "can teach (knows well)," 4 is "can operate," and 5 is "can troubleshoot (can operate at a higher level)."

There are five major categories of responses, each with four or five sub-categories. The major item "Operation and Construction" includes five sub-items such as "OS (Linux / Windows)," "Server (Web server, mail server, DB server)," "Database and access privileges," "User and administrator access control," and

"HTML / JavaScript / PHP / CGI. The major category "Knowledge and Law" includes five subcategories: "OS (Linux / Windows)," "Risk Causes (physical factors, technical factors, human factors)," "Unauthorized Access Prohibition Law and Personal Information Protection Law," "CVE," and "Cyber Kill Chain. The major category "Certification" has four subcategories: "Certificates," "Cookies," "Protocols (HTTP, TCP/IP, IPSec)," and "Basic Authentication. The major category "Vulnerability" has five subcategories: "SQL Injection," "OS Command Injection," "XSS," "Exploits," and "Security Assessment, Vulnerability Assessment, and Penetration Testing. Finally, the major item "Defense in depth" has five sub-items: "Anomaly detection, tamper detection," "Firewall," "DMZ," "IDS, IPS," and "WAF.

Based on the discussion by Jaaska et al. (2022) that Game Based Learning (hereafter GBL) methodology as an educational method may increase student motivation and learning effectiveness, Yonemura et al. (2023) positioned cybersecurity educational materials as Game Based Learning and quantitatively examined the amount of motivation required for effective learning. The participants were asked to answer four questions related to motivation: "Interest in learning cyber security," "Difficulty in learning cyber security on your own," "Are you looking forward to taking the course," and "Expectations for improving your skills after taking the course. Respondents were asked to rate the degree to which they thought about each question on a 5-point scale: 100%, 75%, 50%, 25%, and 0%. A score of 100% was set at 5, followed by 4, 3, and 2, and a score of 0% was set at 1 when we analyze the data. The results showed that a motivation score of 4 was the boundary line separating effective skill development from ineffective skill development, suggesting that an average of 75% or more in the degree of thought to the four questions leads to effective skill development. Since the purpose of this study was also to observe the possibility that motivation contributes to effective learning, the same questions were answered before the course was taken.

Results and Discussion

The 37 students who eventually received credit were divided into two groups according to their motivation scores from the pre-course questionnaire. Based on previous research findings (e.g., Yonemura et al., 2023), we positioned these two groups as the ultra-high motivation group (mean score 4.48, 16 students) and the high motivation group (mean score 4.00, 21 students). Figure 1 shows the mean motivation scores of the two groups after classification. The ultra-high motivation group is on the left and the high motivation group is on the right. All 37 students were highly motivated, as they had voluntarily requested elective courses and had earned credits for them. The high motivation group was further divided into two groups: the high motivation group and the high motivation group. A one-factor analysis of variance with score as a factor showed a main effect of score for both groups (F(1,35)=11.37, p<.005), so we decided to proceed with the analysis for each group, judging that the positioning by score was appropriate.

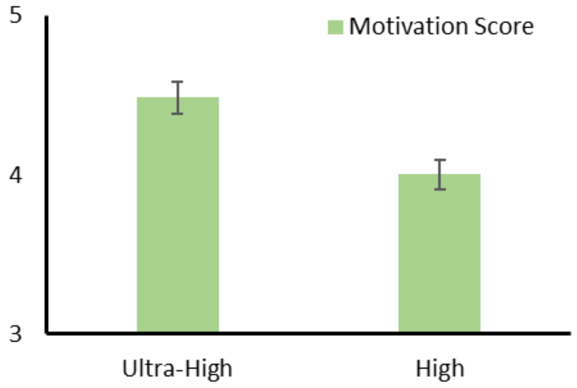

Figure 1 The average of motivation scores for each group when 37 participants were divided into two groups according to motivation score (error bars indicate standard error).

Scores on cybersecurity skills and knowledge of the students who took the course were also obtained through questionnaires before and after the course. The skills and knowledge were the five categories that have been used as indicators in previous studies: operation and construction, knowledge and law, certification, vulnerability, and multilayer defense. We focused on this point because the perspective is whether differences in skill development occur in the two groups we classified.

Figure 2 shows the average of the self-assessment scores of the five skill items before and after the course for the 21 participants in the highly motivated group. Similarly, Figure 3 shows the average of the self-assessment scores of the five skill items before and after the course for the 16 participants in the ultra-high motivation group.

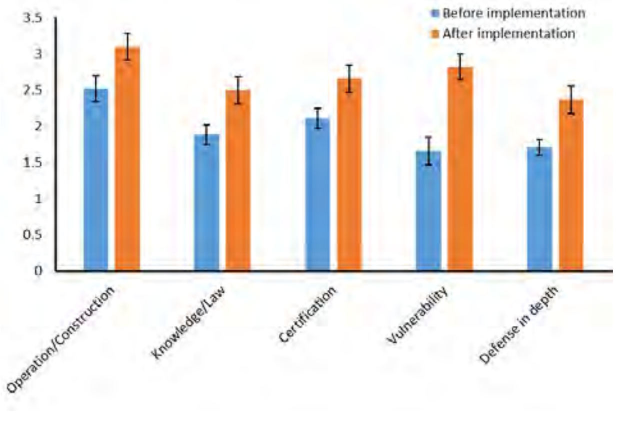

Figure 2 The average of self-rated scores of the five skill items before and after the course for the 21 highly motivated group members (error bars indicate standard errors).

For the highly motivated group, a two-factor analysis of variance with skill items and pre- and post-attendance as factors revealed main effects for skill items (F(4, 80)=13.76, p<.001) and pre- and post-attendance (F(1,20)=24.05, p<.001). The interaction was also significant (F(4,80)=7.32, p<.001). Since the focus was on which of the five skill items had a significant learning effect before and after the course, a simple main effect test for the interaction confirmed that significant learning effects were obtained for all five skill items (Fs(1,100)>=10.65, ps<.005). ps<.005).

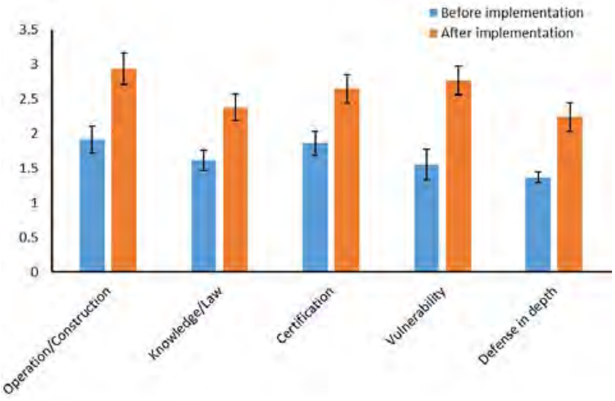

Figure 3 The average of self-rated scores of the five skill items before and after the course for the 16 participants in the ultra-high motivation group (error bars indicate standard errors).

Similarly, in the ultra-high motivation group, a two-factor analysis of variance with skill items and pre- and post-course as factors showed main effects for skill items (F(4, 60)=5.98, p<.001) and pre- and post-course (F(1,15)=37.65, p<.001). The interaction was also significant (F(4,60)=2.64, p<.05). As with the highly motivated group, since the focus was on which of the five skill items had a significant learning effect before and after the course, a simple main effect test on the interaction confirmed that significant learning effects were obtained for all five skill items (Fs(1,75)>=17.20, ps<.001).

These results confirm the results obtained in the previous paper that a motivation score of 4 or higher is associated with a high learning effect. A new point of view in this study was to examine whether there is a difference in learning effectiveness when groups are further classified into groups with a motivation score of 4 or higher. However, since both groups obtained exactly the same results, i.e., significant learning effects were obtained for all five skill items, a so-called ceiling effect occurred, and no differences between the two groups could be confirmed.

In order to examine whether the content of the prepared study and the corresponding skill items grew, we then conducted a two-factor analysis of variance on the score increase for the five items, with the two motivation groups and the growth of the five skill items as factors. A main effect for growth in skill items was found (F(4,140)=8.23, p<.001), but no main effect was found for the motivation group (F(1,35)=1.07, p=031). The interaction was also not significant (F(4,140)=0.95, p=0.44). Since a main effect was found for the growth of the skill items, multiple comparisons confirmed a significant difference with the other four items for the score increase on vulnerability (ts(140)>=3.71, ps<.0003).

This result suggests a high level of skill building and knowledge acquisition on vulnerability, a skill item intended by those who developed and provided the educational materials. However, no difference in learning effects was observed between the two motivation groups.

Although it was not possible to confirm the difference between the two motivation groups due to the occurrence of the ceiling effect, it was confirmed that the assumed skill improvement was appropriately implemented and effective for all participants, and that a motivation score of 4 or higher is sufficient for a high learning effect to be obtained. In order to effectively utilize the results of this study in other subjects, practices in other fields, and other higher education institutions, we conclude that two points are necessary: setting goals based on appropriate historical background and preparing prior learning to further increase interest, since a high motivation score may be an important point.

Conclusions

The development of cyber security personnel is becoming increasingly important in engineering education around the world. kosen has been promoting a cyber security personnel development project since 2015, and our Kisarazu National College of Technology is the base school for the project. in 2022, KOSEN launched an inter-KOSEN credit transfer system. The author, who is in charge of the technical aspects of the project, opened an "Information Security Exercise" course that allows students to learn about vulnerabilities of web applications in a practical manner in order to develop cyber security human resource development by utilizing this system.

While promoting the project and conducting educational effectiveness measurement research, the latest research results had obtained that a motivation score of 4 or higher (on a scale of 1 to 5) indicates a high learning effect. Therefore, we aimed to replicate this result in this course under the KOSEN inter-KOSEN credit transfer system.

When we compared the educational effects of the cyber security skills and knowledge items for 37 participants in the "Information Security Exercise" course offered in the second semester of 2022 before and after the course, we confirmed the high educational effects associated with high motivation scores, thus reproducing the findings we had obtained previously. In addition, the cyber security educational materials used in this study were intended to improve skills related to vulnerability, and skill improvement was observed as intended, suggesting the appropriateness of the content of the practice.

In other words, by having students attend lectures with high motivation, high educational effects can be obtained and skills can be improved as intended. Although this framework and its results are limited to education at KOSEN and the field of cybersecurity at this time, the effects of increasing motivation may be applicable to all educational settings in light of the theory of Jaaska et al. In addition, since learning in the cybersecurity field contains many elements of Game Based Learning, there is a high possibility that the findings can be generalized to fields that have elements of Game Based Learning.

In conclusion, we believe that by working to motivate students by setting goals based on appropriate historical backgrounds and preparing for prior learning to increase interest, it will be possible to increase the effectiveness of education not only in engineering education at KOSEN, but also in all engineering fields at higher education institutions.

In the future, we would like to examine the differences in educational effectiveness due to further subdivided groupings within a motivation score of 4 or higher, which could not be confirmed this time. By focusing on the points in the range of scores where many learners stay, and by zooming in, a more detailed analysis of the same range will be possible, so we will prepare questions that take this into account and conduct a detailed analysis at the next course opening.

The results obtained are expected to make a significant contribution to the analysis and application of new educational effectiveness measures.

Acknowledgements

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IMPLEMENTATION OF THEMES FOR SUBJECT OF MANUFACTURING BASIC FOR FIRST-YEAR STUDENTS TO SELECT MAJOR COURSE

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Abstract

At the National Institute of Technology, Nagano College, from the fiscal year 2022, all first-year students enter the engineering department without choosing a major. The students will choose to major in one course out of Informatics and Electronics, Mechanics and Robotics, or Civil Engineering when they advance to the second grade. To provide an opportunity for students to select a major, these general subjects are provided - basic manufacturing engineering and basic manufacturing experiments. These subjects are provided based on the five original fields the school offered. We hope students will be motivated to select a major and increase their motivation for future study through these subjects. Each of these two subjects is arranged for 90 minutes, which totals 180 minutes per week. Each of the original fields will be covered for 3 weeks in the first semester and 3 weeks in the second semester, for a total of 6 weeks. The course of Informatics and Electronics (IE) consists of the former "Department of Electrical and Electronic Engineering" and "Department of Electronics and Computer Science". The course of IE consists of the information and the electronics field. We examined the themes and content for the first three weeks and the second three weeks, for six weeks. Three themes were set: machine learning, information security, and application development. In the theme of machine learning, students will study image recognition and image generation, focused on machine learning such as AI and deep learning. In addition, we hope it will lead to a new curriculum on data science that will be established for all departments. In the theme of information security, students learn about the properties of files handled by computers and the information contained in files, focusing on image files mainly. Security is an issue in the information society, and security engineers are required. We believe this will lead to security-related subjects being offered in the following year's curriculum. In the theme of application development, students will have experience programming a smartphone application. Students are familiar with smartphones and interested in programming through games, etc. In addition, our curriculum has many opportunities for programming as well. By using a tablet, we hope students can experience manufacturing through programming. In this paper, we show the results of implementing these themes, we have discussions based on the state of classes and the results of questionnaires.

Keywords: *freshman education, major select, machine learning, information security, application development*

Introduction

At the National Institute of Technology, Nagano College, all first-year students enter the engineering department without choosing a major, from the fiscal year 2022. After entering it, the students will choose to major in one course out of Informatics and Electronics, Mechanical Robotics, and Civil Engineering. at the end of the first year (Table 1). To provide an opportunity for students to consider and select a major, basic manufacturing engineering and basic manufacturing experiments are set. These subjects are provided based on the five original fields the school offered.

We belong to the course of Information and Electronics, which consists of the former Department of Electrical and Electronic Engineering and Department of Electronics and Computer Science. The IE course brings the subject separated by two fields: information and electronics (Table 2).

Basic manufacturing engineering and basic manufacturing experiments, each subject have 90 minutes per week, and these are offered consecutively throughout the year. We thought that it would not be necessary to divide the two subjects clearly, as long as these subjects could be evaluated separately.

Table 1 Department of Engineering and Course

1st Grade	2nd Grade	3rd-5th Grade
Department of Engineering	Course of Informatics and Electronics	Informatics course
		Electronics course
	Course of Mechanics and Robotics	
	Course of Civil Engineering	

Table 2 Old Department and New Course

Old Department	New Course
Electronics and Computer Science Engineering	Informatics and Electronics
Electrical and Electronic Engineering	
Mechanical Engineering	Mechanics and Robotics
Electronics and Control Engineering	
Civil Engineering	Civil Engineering

Table 3 Class and Course Rotation Table

	Class				
Week	1-1	1-2	1-3	1-4	1-5
1	IE1_1	MR1_1	CE_1	IE2_1	MR2_1
2	IE1_2	MR1_2	CE_2	IE2_2	MR2_2
3	IE1_3	MR1_3	CE_3	IE2_3	MR2_3
4	IE2_1	MR2_1	IE1_1	MR1_1	CE_1
5	IE2_2	MR2_2	IE1_2	MR1_2	CE_2
6	IE2_3	MR2_3	IE1_3	MR1_3	CE_3
7	MR1_1	CE_1	IE2_1	MR2_1	IE1_1
8	MR1_2	CE_2	IE2_2	MR2_2	IE1_2
9	MR1_3	CE_3	IE2_3	MR2_3	IE1_3
10	MR2_1	IE1_1	MR1_1	CE_1	IE2_1
11	MR2_2	IE1_2	MR1_2	CE_2	IE2_2
12	MR2_3	IE1_3	MR1_3	CE_3	IE2_3
13	CE_1	IE2_1	MR2_1	IE1_1	MR1_1
14	CE_2	IE2_2	MR2_2	IE1_2	MR1_2
15	CE_3	IE2_3	MR2_3	IE1_3	MR1_3

In this paper, we confirm the purpose, set themes, and examine the contents.

Purpose

In parallel with the implementation of basic manufacturing engineering and basic manufacturing experiments throughout the year, a major survey will be conducted three times (initial, intermediate, and final), and a major will be determined finally.

Therefore, basic manufacturing engineering and experiment will be opportunities to choose their major and learn the basics of engineering for first-year students.

As a theme for the information field in the course of Informatics and Electronics, we examined the content that would have the effect of increasing the motivation to study in the information courses.

The main purpose of these themes was to provide an opportunity for students to choose information electronics, and to provide an overview of information courses. Furthermore, even if students do not choose the course of Informatics and Electronics, and Information courses, since there are opportunities to utilize information technology in any field, we want students to keep the motivation to understand the knowledge of information technology.

The basic manufacturing engineering and experiment are provided by each old department field. The rotation of class and course are shown on Table 3. The IE1 means the Department of Electrical and Electronic Engineering, IE2 means the Department of Electronics and Computer Science Engineering. And MR1and MR2 means the Department of Mechanical Engineering and the Department of Electronics and Control Engineering. The CE means the Department of Civil Engineering.

Each field provide themes by 3 weeks and rotate to another class. It repeats for 15 weeks. And same pattern is provided in second term too.

Themes

The following three topics were established as the themes for Information courses in course of Informatics and Electronics.

(1) Machine learning
(2) Information security
(3) Application development

In the first three weeks, (1) Machine learning for two weeks, (2) Information security for one week, and (3) Application development in the latter three weeks.

In (1) Machine learning, this theme is image recognition and image generation, related to machine learning such as AI and deep learning. Interest in this field has been increasing recently, and students are interested in it. In addition, this subject will lead to a new curriculum on data science that will be established for all major departments.

In (2) Information security, the main target of the theme is images, regarding the properties of files handled by computers and the information contained in files. In the information society, information security is emphasized, and there are high demands for engineers with security technology. We believe that this will lead to security-related subjects that were added to the new curriculum.

In (3) Application development, the theme provides experiences to manufacture using programming. Students are familiar with smartphones and are interested in programming through games, etc. In the Information course curriculum, there are many opportunities to learn programming. Therefore, by creating a smartphone application that can be executed on a tablet, students can experience manufacturing through programming. This is refined content based on provided to first-year students of the Department of Electronics and Computer Science in 2019(Fujita and Nishimura, 2020).

Contents

The specific contents of the three themes are shown below.

About (1) Machine learning, students learn the basic knowledge and background related to artificial intelligence, students will experience recognition of handwritten numbers, image synthesis, and reinforcement learning, using the Python language. At first, the theme teacher described the historical trend and current state of artificial intelligence as an introduction. As the first approach, the teacher made students recognize numbers using MNIST data as image recognition. Let each student create ten pictures of numbers from 0 to 9 with paint software. The teacher asked students to try how the numbers were recognized. After that, the ten pictures of numbers created by all the class members were collected in a shared drive and tried to see how they were clustered. As a second approach, as an attempt at the generative adversarial network, students synthesized two pictures. Each student created two pictures using paint software and combined these pictures into the generated picture. Finally, we learned the concept of reinforcement learning, applied it to an action game, and tried a game example that was reflected in the action.

About (2) Information security, the information contained in image files, students learn how to read file headers and extensions, how to read binary files, and how to edit them. As exercises, students try to analyse the given image. At first, students learn basic knowledge such as the types of digital images. Next, they confirm that the GPS and shooting information are included in the image, and check variation of the header information of the file. Next, they try reading the file using a binary editor, they can directly view and edit binary files. They learn that various information is included in the content of the image in binary data. After confirming these with the example file, they have exercises to find the implemented data contained in other files. For the first 30 minutes, they try individually, and after that, they can have discussions with nearby students. After students submit the response, the theme teacher showed the answer.

About (3) Application development, students create applications that run on a tablet in Java language from scratch using Android Studio. At first, students try to create an application “do nothing” with the wizard. Then create an app that calculates Body Mass Index (BMI). After that, students create an original application from the below list: ingenuity application of BMI calculates, form format application, and completely original application. At first, the theme teacher explained the environment required to create an Android application.

Students learn the procedure for creating an application in Android Studio to create a "do nothing application" and check how the application is created on the tablet. Next, students create an application that calculates and displays BMI by inputting height and weight and pressing a button. At last, they create an original application. A theme teacher shows three categories. Ingenuity application case, it adds any information to the result display of the BMI application. Form application case like a BMI app, to enter data and press a button to display the results. Completely different application case, it needs high skills.

Results

Here are the results of a theme devised for first-year students in 2022. We show preparation for implementation, the state of classes, questionnaire taken at the end of each class. The target students are first-year students, and they have their own Windows laptops. It is possible to practice on their own PC that they have brought with them. In addition, they have a Microsoft account and a Google account, so it is possible to use these services.

About preparation for three themes for each. In the theme of machine learning, we confirmed that the exercise can be implemented in Google Colaboratory. Since the students have Google accounts at school, we confirmed that they can be used using that account. In the theme of information security, since we work on exercises and assignments to explore the information contained in images, we prepared images for students to explore related information, as well as a binary editor that can edit binary files. In the theme of application development, we prepared PCs with Android Studio as an application development environment. This is because we thought that installing the development environment on students’ own PC would be a high hurdle for first-year students. And we also prepared a tablet that can run the application.

Regarding class structure, for the three themes, two weeks of machine learning and one week of information security were implemented in the three weeks of the first semester. Three weeks of application development were implemented in the latter three weeks of the second semester. This pattern is applied to 5 classes.

Regarding the state of implementation, in the theme of (1) Machine earning, own drawing pictures by students had become input data for AI. As for recognizing numbers, students tried to write numbers in a way like other numbers, or they write is so that they would be difficult to read. By increasing the number of times of learning and increasing the number of layers, students confirmed the recognition rate increased. As unsupervised learning, the numbers of pictures created by everyone were classified into ten types, and the results of clustering were shown by themselves. Figure 1 shows the ideal of clustering by handwriting number.

In the practice of generative adversarial network, students who were interested in drawing tried to draw elaborate pictures or anime character pictures, as input

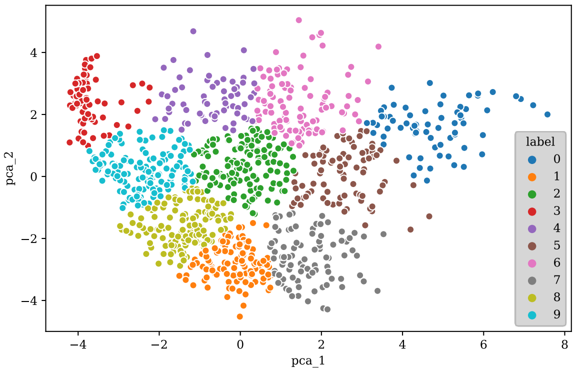

Figure 1 Ideal of Handwriting Number Clustering

解析した画像

イメージ

2.49 MB

EXIF情報

メイン情報 サブ情報

メーカー	Apple
カメラ	iPhone X
画像方向	回転なし
幅の解像度	72
高さの解像度	72
解像度単位	インチ
ソフトウェア	14.7.1
ファイル変更日時	2021年10月06日 09時58分05秒
HostComputer	iPhone X
TileWidth	512
TileLength	512
画素構成	1

Figure 2 Hidden Data Implemented in Image

pictures. When creating the pictures, it was observed that problems were occurring at the time of implementation, as they worked on conditions such as resolution and color restrictions without listening to the teacher's explanations and instructions.

About states of implementation in the theme of (2) Information security, students confirmed that contained data (Figure 2) in the image using a web service (TETRA, 2021).

Some students were surprised that the location can be specified by latitude and longitude included in the picture file. In the step of using a binary editor for the file header, many students had puzzled by the difference in usage between opening a file with a binary editor and with a normal editor. At the step of exercises, some students tried other methods than learned earlier methods. Some had used web services, and image search engines. As time passed, some tried to use a binary editor.

About the state of implementation in the theme of (3) Application development, when students created a "do nothing application" in the first step, some are surprised that could make a smartphone application easily. Next, students create the interface of the application that calculates BMI and display it on the tablet (Figure 3). After they wrote programs by reference to the textbook, completed that can calculate BMI by inputting height and weight and pressing buttons.

Finally, I instructed the creation of an original application. At first, some seemed confused about what to do, they refer to textbook that explained how to use checkboxes and radio buttons and control architecture. Some create simple fortune-telling applications and diagnosis applications were created. As a device of the BMI application, some add health advice that is displayed using conditional judgment from the diagnosis result. During the last class time of creating the application, some students showed their applications to each other.

It shows questionnaire results. In the last frame of the last week of the application development theme, we conducted a questionnaire on the three themes. However, due to preparation reasons, questionaries applied to only four of the five classes.

One question is "Please rank 1, 2, 3 (1 is the highest) in order of interest in the content of the information course". The results of the question are as Figure 4.

19:03

BMIcalculator

身長 身長を入力する cm

体重 体重を入力する kg

計算

計算結果がここに表示されます

19:20

BMIcalculator

身長 175 cm

体重 65 kg

計算

BMIは21.2

Figure 3 BMI Calculator Application

From this result, there is a high interest in the theme of application development. In the question, it has a column to write the reason for adding 1-3. The following descriptions are written. The reasons for his high interest in machine learning are: "I was surprised that a machine could distinguish numbers", "I had learned a lot about AI", and "Because I like to think of my own goals and how to achieve them." The reasons for his high interest in information security are: "I could learn things that are not visible in normal use, such as file formats and structures.", "It's interesting that a single image contains many data.", "I could see the other side of what I usually use." The reasons for showing high score for application development are: "I felt a sense of accomplishment after completing the application development." "I could create a practical application by myself.", "I could program like I had imagined, not just copy and paste."

However, according to the reason for ranking, we could evaluate some answers are inappropriate choices or not accurately reflect opinions for the question. For example, there are descriptions such as "I am interested in machine learning because I entered this school with an interest in machines.". Some students couldn’t understand the connection between the theme and the course. In addition, there are descriptions such as "I don't remember what I did" about machine learning and information security. It seemed that some students

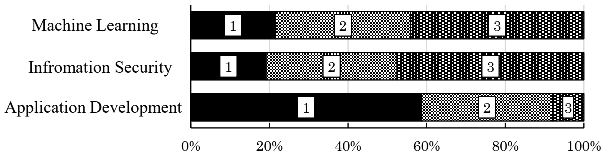

Figure 4 Ratio of 1-3 ranking for themes

couldn't be connected between the listed theme and the contents of the previous term.

Discussion

It shows the status of implementation. Each theme was able to be implemented as planned.

In the theme of machine learning, students could experience AI by creating an image as an input for learning by myself. The experiences are automatic discrimination by clustering in unsupervised learning, recognition rate improvement by increasing the stage and number of times of learning, etc. It seems that interest in the processing and performance of AI has increased. It is thought that students could comprehensively learn about general techniques related to machine learning. On the other hand, we provided a part to input the prepared Python program, they execute the program process, but it seems that it was not enough to give a real feeling of manufacturing.

In the theme of information security, students were surprised to find that the file contained an unexpected of information. In addition, as for file operations, it seems difficult to use because of the peculiarities of a binary editor. However, some students are trying to find out the contents of the file by using it somehow, and some students have a growing desire to hack. It seems that the impressions depended on students according to their aptitude as an information security engineers.

In the theme of application development, the class has a style that students proceed along to demonstration by the teacher, but some students felt it was early. One reason for this is thought the difference in familiarity with computer operation. Some were surprised at how easy it was to develop applications. We think that the reason is the interface was created using a GUI. In the original application, the students seemed to enjoy being able to create their own applications. During class time, students ask teachers how to use images and sounds and set colors. We taught them how to do it and explored it with them, and they seemed happy with the result. It can be considered that they enjoy the application development to turn their own ideas into the smartphone applications.

On the other hand, some students ended up feeling that it was difficult. For students who like a learning style that builds up step by step, the experience style maybe imposes a burden on students.

It shows discussion about interest in each theme through questionaries results.

From the results of the questionnaire, they were most interested in application development. I think that the reason for this is that students did the developing applications by myself. In the BMI application, they copied and pasted the text for the program part, but they created the interface and set the association between the interface and the program by themselves. In the original application development part, we provide time to do it on their own. Students could try the creation by their voluntarily, we thought it increases their interest in this theme. However, students who have little interest in IT, might think programs harder than they had to do or they may be annoyed by programming little mistakes. It might lead to feelings of inadequacy. Some responded that they enjoyed application creation and that they wanted to devise more. In the next year, they will learn programming from the beginning. So, we want to provide that they can learn it while keeping in mind that it is the knowledge that can be used in programming learning.

From the result of the questionaries, interest in machine learning was not very high, but it is possible that it was not remembered because it was the first time. It is also possible that the name" machine" gave students a different impression. Even just emphasizing "AI" seems to make the result different from the questionary. Of course, some topics make interest high, such as improving automatic number recognition and clustering. It is thought that it can be based on actual utilization and application in data science subjects that will be held in the future.

From the result of the questionaries, interest in information security is the lowest. It is considered an intriguing topic for students who are highly interested in information processing. For example, hacking with a binary editor is an unusual experience that couldn't do in the common usage of computers, and deep knowledge is required. For information security engineers, it requires a wide knowledge of the whole and deep knowledge of each part. For such students who are interest in this theme, it is better not only to have subjects on information security in the school curriculum but also to encourage them to participate in security camps and event of CTF (Capture The Flag).

Improvements

Next year, it is decided that subject week times will be five weeks for each field. In the final five weeks, 3 weeks for common learning for all classes, and two weeks for each course learning for major course classes (Table 4). The number of times of implementation in 5 fields will be reduced from 6 weeks to 5 weeks. In the information course, we planned to reduce application development from 3 weeks to 2 weeks. As a result, we reduce one week to creating an original application. It is necessary to verify how this affects students' interests.

About the theme of machine learning, we name the theme Artificial Intelligence. It makes students the image to information processing and data science instead of the mechanical engineering field.

About the theme of information security, we plan to update the content. It will be changed to contents so that students can learn color processing and image files deeply.

Conclusions

At the National Institute of Technology, Nagano College, the subjects Basic manufacturing engineering and basic manufacturing experiments have been established for new students in the 2022 fiscal year. The main purpose of these subjects is to introduce fields of the course that they belong to in their second year.

Table 4 Class and Course Rotation Table in 2023

	Class				
Week	1-1	1-2	1-3	1-4	1-5
1	IE1_1	MR1_1	CE_1	IE2_1	MR2_1
2	IE1_2	MR1_2	CE_2	IE2_2	MR2_2
3	IE2_1	MR2_1	IE1_1	MR1_1	CE_1
4	IE2_2	MR2_2	IE1_2	MR1_2	CE_2
5	MR1_1	CE_1	IE2_1	MR2_1	IE1_1
6	MR1_2	CE_2	IE2_2	MR2_2	IE1_2
7	MR2_1	IE1_1	MR1_1	CE_1	IE2_1
8	MR2_2	IE1_2	MR1_2	CE_2	IE2_2
9	CE_1	IE2_1	MR2_1	IE1_1	MR1_1
10	CE_2	IE2_2	MR2_2	IE1_2	MR1_2
11	IE1_1	MR1_1	CE_1	IE2_1	MR2_1
12	IE1_2	MR1_2	CE_2	IE2_2	MR2_2
13	IE1_3	MR1_3	CE_3	IE2_3	MR2_3
14	IE2_1	MR2_1	IE1_1	MR1_1	CE_1
15	IE2_2	MR2_2	IE1_2	MR1_2	CE_2
16	IE2_3	MR2_3	IE1_3	MR1_3	CE_3
17	MR1_1	CE_1	IE2_1	MR2_1	IE1_1
18	MR1_2	CE_2	IE2_2	MR2_2	IE1_2
19	MR1_3	CE_3	IE2_3	MR2_3	IE1_3
20	MR2_1	IE1_1	MR1_1	CE_1	IE2_1
21	MR2_2	IE1_2	MR1_2	CE_2	IE2_2
22	MR2_3	IE1_3	MR1_3	CE_3	IE2_3
23	CE_1	IE2_1	MR2_1	IE1_1	MR1_1
24	CE_2	IE2_2	MR2_2	IE1_2	MR1_2
25	CE_3	IE2_3	MR2_3	IE1_3	MR1_3
26	Common Learning				
27					
28					
29	Course Learning				
30					

In the informatics field of the Course of Informatics and Electronics, machine learning, information security, and application development were set and implemented as the contents of the subjects.

Students had been interested in application development, machine learning, and information security, in this order. But all of the themes had been interesting in students for each specialized knowledge for succeeding subject.

In the next fiscal year, the time for themes will be reduced by one week. And the other themes also fix contents based on the result of implementations and environments. We have to confirm the impacts of the change. Including this change, we would like to raise the interest of students and consider the effect of the following curriculum.

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"Critical Thinking in English": CLIL Methods Increase Student Participation

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Abstract

The purpose of the one-semester "Critical Thinking in English" course in the from April 2021 to September 2021 at the Tokuyama campus of The National Institute of Technology in Japan, was to engage students in more active learning and increase their perception of English as a useful skill. The course was based on CLIL methodologies, placing equal emphasis on the subject (critical thinking) and the classroom language (English). Since the key to increasing student interest is to maximize the perceived relevancy of the subject to the students' educational goals, the importance of critical thinking skills was explored on the first day of the course. Also explained at the outset was the purpose of studying critical thinking in English: thinking in a foreign language forces people to consider their decision-making processes, their word choice, and their responses. Over the next 15 lessons, students practiced various critical thinking strategies in English over five thematic units. A survey of the 110 students who completed the course indicated a positive reception of the course, its goals, and its methods. Of the 110 students who completed the course and the survey, 65 students said they would highly recommend this course to other students; 70 indicated they had no idea what critical thinking was before taking the course; 77 said practicing critical thinking in English is important; 79 stated the course was helpful in reaching their education goals; and 93 said their critical thinking skills improved. Such results suggest that increasing student engagement in English language courses depends on underlining its perceived authenticity and relevancy. Further, this type of foreign language course can raise students' speaking time, motivate the students' active engagement with the learning materials, and heighten their perception of the L2 as an indispensable part of their mental toolkit. This approach to foreign language classes should be used more because such CLIL-based English language classes focused on the subjects perceived as relevant to the students' own educational and life goals—rather than primarily on grammar and vocabulary—have more of a chance of engaging students in active learning.

Keywords: *CLIL, English, Critical Thinking, Engagement, Motivation*

Introduction

In 2021, 5th year students at The National Institute of Technology, Tokuyama College (NITTC) completed a course titled "Critical Thinking in English." This course was based on Content and Language Integrated Learning (CLIL) methods to address perceived inadequacies of current EFL teaching methods at the institution as indicated in an analysis of a 2017 survey of 493 NITTC students. In this survey, students agreed that they want more chances to use English outside of school, and that people outside of school do a good job of helping them understand how English is relevant to their lives after graduation; however, most students disagreed that English is relevant to their daily lives and that they seek resources for studying English outside of regular schoolwork. From these statements, we concluded the following:

1. The students perceive that English is important to learn.
2. The students do not perceive that English will be useful in their life after or outside of school.
3. "English is important" is a message they received from various people and sources, but it is divorced from their daily experience.

Based on these conclusions, this teacher decided to start an English course aimed at fostering an awareness of English as being useful in their present education and their future careers, and at increasing students' perception of the English they learn at school as being authentic and relevant. Such an English course should emphasize communication, not the mastery of technical terms and grammar. The course should focus on building the perceived authenticity of the classroom language. To establish relevancy between English as a language of communication and the students' lives, the materials being studied in the classroom need to be selected and presented in a manner that increases their perceived authenticity. CLIL methods seemed the perfect fit for these goals. To this end, "Critical Thinking in English" was offered to all fifth-year students at NITTC.

Propositions to use CLIL methods in classrooms in Japan are often met with concerns from teachers, students, and students' parents, primary of which relate to the dual focus of CLIL: won't focusing on both subject content and language content mean that students will have less chance to learn either subject or language? This concern has been echoed and addressed by several researchers into CLIL in Japan. Published research indicates CLIL does have a positive impact on student motivation and engagement in language learning. One study by Myowa-Yamakoshi and Machida (2018) examined the impact of CLIL on EFL learning in a Japanese high school and found a positive effect on learners' engagement and motivation in EFL learning. Tsuchiya (2019) noted that a survey of 21 articles in secondary CLIL practices in Japan showed positive effects of CLIL on learning. Yamano (2019) showed that CLIL enhanced classroom engagement and cooperative learning. In a 2017 study of Japanese university EFL classrooms, Noguchi found that CLIL increased learner engagement and improved their language skills. Similarly, Hughes and Hashimoto's (2018) examination of the effects of CLIL on Japanese university students' English proficiency, motivation, and attitudes found positive correlations between CLIL and English proficiency and increased student motivation and engagement. Another study by Imamura (2018) investigated the impact of CLIL on motivation, attitudes, and listening ability of Japanese high school EFL learners, and found heightened motivation and listening ability. Additionally, Kanehiro (2018), in exploring the impact of CLIL on student engagement in an EFL classroom in a Japanese university, also observed enhanced student motivation and engagement. These studies indicate CLIL can improve language proficiency and other academic skills and contribute to a more engaging and motivating learning experience for students. Yet, further research is needed to explore the specific factors that contribute to the effectiveness of CLIL in the Japanese context. Keiko Tsuchiya notes a common concern: that "students may learn less subject knowledge through CLIL because of the difficulty in learning content in addition to language" and "that CLIL classes may hinder students' language learning" (p. 48). However, it will be shown that in the case of "Critical Thinking in English" not only did CLIL increase student motivation and engagement in the learning process, it also did not detract from acquisition of subject knowledge.

Materials

"Critical Thinking in English" (hereafter referred to as CTE-CLIL) was a 16-week course (one semester), covering six thematic units: "Anime vs. Manga," "Social Media and Humans," "Solar Energy Benefits and Drawbacks," "Robots, AI, and Human Employment," "Population Problems," and "Benefits and Drawbacks of Cram Schools." These topics were chosen according to considerations of students' interests, relevance to students' education and future career goals, and based on student reactions in previous CTE-CLIL courses.

All materials were written in English, and all materials were prepared and developed by the instructor. These materials included printed handouts for students and online materials. The online materials were made available to students through Microsoft Teams and in Kahoot. For those not familiar with these platforms: Microsoft Teams is the current LMS used at Tokuyama College, and Kahoot is an online quiz generator. Printed handouts were five pages, detailing the questions, texts, vocabulary, and homework the students would be completing in that thematic unit. The first two pages of the handout were designed to be covered in the first class of the unit, the third page was homework to be done after the first class, and the final two pages were to be covered in the second class of the unit. The handouts primarily consisted of text, with minimal graphics. Online materials included vocabulary, grammar, and reading quizzes in Microsoft Forms, and similar quizzes and opinion polls in Kahoot. All materials were accompanied by concurrent in-class slide presentations in Microsoft PowerPoint, which students had access to both before and after the lesson through postings in Microsoft Teams.

A brief overview of the first two pages of a sample handout from the first thematic unit "Anime vs. Manga": 1) a prompt for pair talk, in English, introducing the topic; 2) listen and repeat sample responses; 3) a prompt for pair talk; 4) vocabulary check in which students research and write the definitions for key vocabulary; 5) revisiting the key question: "Which is better, anime or manga?" 6) a prompt to consider the quality of the key question; 7) considering the key question in different situations; 8) vocabulary check; 9) reading; 10) conversation prompt based on the reading; 11) discussion with partner based on new understanding of the key question.

Homework typically consisted of two to three activities: 1) interviewing people outside of the classroom with a question related to the unit theme, 2) reading, 3) answering questions about the reading.

The final two pages of the handout start with a review of the homework, in which classmates share the results of their interview. After that, ideas or questions considered in the first previous lesson are expanded upon or looked at in more detail. More, relevant vocabulary is introduced, followed by another reading, and then an examination of concepts introduced in the reading. Finally, there are plenary activities such as debates, role-plays, or questionnaires, all designed to encourage students to interact as a class, as opposed to interacting in pairs or small groups.

Methods

This course was listed as "合英語演習II" (Comprehensive English Exercises II) in the syllabus. Students' grades were evaluated according to the following criteria: 40% homework, 40% quizzes and class participation, and 20% based on their score in the TOEIC taken outside of classwork and according to the policies of The National Institute of Technology.

The "CLIL" of "CTE-CLIL" stands for Content and Language Integrated Learning, an internationally recognized method of English teaching that emphasizes the concurrent teaching of a foreign language and a subject content. In CLIL, there is an equal emphasis placed on the acquisition of the foreign language and of the subject content. In CTE-CLIL, the foreign language the be acquired was English, while the subject content was critical thinking skills. This dual focus was made clear to the students through the syllabus: “In this course, students will engage in discussions and activities which help them improve their critical thinking skills and their use of the English language. The focus of this class is engagement and conversation, not grammar and vocabulary.” This dual focus was again emphasized on the first day of class, and periodically in subsequent lessons, as the stated learning objective of the course: “Critical thinking means thinking about your thinking to make your thinking better. Poor critical thinking skills can lead to a poor quality of life. In this class, we use English as a tool by which to improve our critical thinking skills. Thinking in a foreign language makes us think slower and more carefully. Sometimes, thinking in a foreign language makes us think in different ways than usual.” In this way, the dual focus of the course was made apparent to the students, and all the materials and methods of the course were focused on achieving these goals. However, English was not the exclusive language of the course.

The students’ native language was not forbidden in the classroom, but it was discouraged in favor of English given the learning objective of the course. In fact, students were sometimes prompted to use their native language to discuss ideas together. Key English vocabulary was researched by the students and written in the native language. At various times chosen as appropriate to lesson goals, the teacher used the students’ native language to check comprehension, to explain difficult concepts or examples, or to answer student questions. Each lesson had a set frame aimed at increasing student understanding and involvement in the learning process.

First, the teacher would announce the schedule for that day’s lesson (the main activities of the lesson and any homework to follow), which would also be written and displayed on a PowerPoint slide. The purpose of this announcement was to make it clear to students the end-goal of the lesson and how each step of the lesson would give students the tools they would need to successfully accomplish the final task(s) of the lesson—in essence, each lesson is structured as a PBL: there is a project (the end goal), and the students work together with the guidance and assistance of their teacher to learn and develop the tools necessary for completing that project.

Second, the students would either discuss in pairs in English a critical thinking question related to the unit’s theme or the homework they had completed prior to the lesson. These critical thinking questions were repeated throughout the lesson, with students asking and answering the questions in a variety of situations or in relation to a variety of input. These questions guided students to focus on different aspects of critical thinking: purpose, question, information, inferences, concepts, assumptions, implications and consequences, and point of view.

Subsequent activities functioned by and large as language input: sometimes activities provided students with vocabulary and grammar templates for answering key critical thinking questions. Students were also notified, repeatedly, that in the interests of communication, the grammar they should use should be kept simple and kept to what structures they were already familiar with and had studied in school—that unnecessary complex grammar and vocabulary might inhibit communication with others and might make this English less useful as a tool for improving this student’s critical thinking skills. By this means, the teacher hoped to emphasize that the main purpose of CTE-CLIL was to improve the students’ use of English as a tool for improving their critical thinking skills (the dual focus of CLIL), not exclusively to improve their English conversation skills or increase their points on a future English test.

Most of the in-class activities were chosen or designed to encourage communication between students, either in pairs or in plenary. Some activities were designed to build from pair work to plenary discussions. Some of these activities were based on readings, others on ranking activities, and still others on researching information online. Regardless of the activity, the teacher emphasized that “there is no correct answer” to ease potential nervousness about sharing ideas and contributing to discussions.

The teacher provided minimal feedback on grammatical or vocabulary mistakes, only those which seriously detracted from the teacher or other students from communication, keeping in mind that the stated learning objective was to use English as a tool by which students would work to improve their critical thinking skills. The various activities took short amounts of time, between 3-5 minutes, so the teacher was able to circulate through the classroom and provide frequent direct feedback or gather examples to provide feedback to the class. The teacher tried to provide both examples of good uses of English and examples of English that needed some correction. Whenever possible, the teacher tried to elicit such correction from the class instead of providing it themselves, to help the students gain both confidence in their own English skills and motivation to participate in the learning process. Of course, some activities, such as those in Kahoot or in Forms, provided the chance to display written productions from students, and these gave the teacher chances to provide more visible examples of both good uses of English and English in need of correction.

Given that improving the students’ critical thinking skills was the stated objective of the course, one unvarying aspect of the homework was to ask for opinions from other people outside the classroom. Asking for and understanding the opinions of others is recognized as an essential critical thinking skill. The teacher encouraged students to interview people they might not usually talk to about these topics: other teachers, family members, and neighbors—unfortunately, given the students’ busy lives or small social circles, interviews were often conducted with classmates not enrolled in "Critical Thinking in English."

Results

To gauge student perceptions of the course, a survey was given to all students who participated in CTE-CLIL. An identical survey was then given one year later to students who participated in "English Conversation," a course that contained minimal CLIL methods and a very different learning objective. We will not look at this analysis in detail, but instead summarize its results because of what they suggest about the effectiveness of CLIL methods in improving student involvement in the learning process.

CTE-CLIL took place one year prior to "English Conversation" (EC). Both courses were listed in the syllabus under the same name. The two courses had very different learning objectives: CTE-CLIL to use English as a tool to improve critical thinking skills, and EC to improve English conversation skills. EC used a professionally developed textbook and multi-media materials. CTE-CLIL used handouts and materials developed by the teacher and, given that this course took place one year prior to EC, a less experienced teacher. Moreover, this teacher already had four years of experience teaching with the materials used in EC, but no experience using the materials of CTE-CLIL. This is significant because even though students in EC gave a higher score to teacher performance and classroom materials in a survey given to all students in both CTE-CLIL and EC, the EC students gave lower scores to their course in all other parts of the survey. Even though CTE-CLIL had lower quality materials, a less developed course structure, and a less experienced teacher, it nonetheless outperformed EC in several key categories. A summary analysis of this results of this survey comprises the final part of this paper.

For "Teacher Performance and Class Materials," EC scored higher by a slight amount, likely due to having a more experienced teacher using professionally developed materials. For the purposes of comparision, then, the two courses were similar enough to more clearly observe the effects of CLIL in the classroom. In "Perceived Effectiveness of Education," more students in CTE-CLIL felt increased confidence in English and a better understanding of the subject content, indicating that a CLIL course can succeed in its dual focus on foreign language instruction and subject content. In terms of "Perceived Authenticity or Value," a higher percentage of students felt CTE-CLIL provided a more authentic or valuable education environment that helped them achieve their educational goals. For "Perceived Interest and Confidence in English," CTE-CLIL students indicated increased interest in English at a slighlty higher rate (from 1% to 3%), suggesting CLIL's effectiveness at hightening student interest in the foreign language. Finally, in terms of "Perceived Critical Thinking Awareness," CTE-CLIL students indicated they gained a better understanding of the subject content (critical thinking). Given that students in CTE-CLIL also indicated an increased understanding and confidence in English, this indicates the dual focus of CLIL did not distract from the content in favor of the foreign language or vice versa.

Considering these results, it is reasonable to assert that, at least as measured by student evaluations of the two courses, the "Critical Thinking in English" course succeeded in meeting the two goals set by the teacher for its implementation National Institute of Technology, Tokuyama: 1) foster in students an awareness of English as being useful in their present education and their future careers, and 2) increase students' perception of the English they learn at school as being authentic and relevant. Beyond these modest goals, the results of this survey indicate that CLIL methods have potential of improving the perceived effectiveness of education, and of increasing student interest and confidence in using English. The use of CLIL methods in class did not distract from the educational goals of the class, did not overburden students with "too much" subject matter, and did not reduce the perceived effectiveness of education in either the target subject or the language of instruction. Indeed, the use of CLIL methods enriched the learning environment by challenging students to use English as a tool to benefit both their current educational goals and their lives outside and after school. In the case of "Critical Thinking in English" the use of CLIL methods increased student motivation and engagement in the learning process, and it did so in a manner that did not detract from acquisition of the critical thinking skills that were the subject content.

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PRACTICE REPORT ON QUIZ-CREATION ACTIVITIES IN ENGLISH CLASSES

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Abstract

The new curriculum guidelines promulgated by the Japan Ministry of Education, Culture, Sports, Science and Technology indicate that teachers must develop student-centered classes. Greater attention is recently being paid to active learning (AL) as a means of carrying out this guideline. English teachers in Japan should teach students the four skills of reading, listening, writing, and speaking, equally. However, traditionally, reading skills, and learning English grammar have received the focus under the Grammar-Translation Method. Little attention has generally been paid to speaking as a skill. In particular, when students learn English grammar, they sit down quietly, listen to the teacher's explanation of the grammar, complete the grammar exercises, and check whether their answer is right or not. They have little chance to speak English. Teachers find it difficult to create a student-centered learning environment and encourage students to speak English when they present English grammar. This paper includes my practice report on English classes for first year students at Kushiro College, National Institute of Technology. I created a student-centered environment that I took advantage of when I taught English grammar to the students. This is a quiz-creation activity, which I call "Guess-de-show!" In this activity, students learn reading, writing, speaking, and listening skills through the creation of quizzes. After the students listen to an explanation of English grammar, they use their newly acquired grammar to create quizzes and hints. Students must read English documents to obtain the necessary information for creating quizzes and hints, providing them to the respondents. The respondents listen to the questioners and respond to the quizzes in English. This is an easy exercise that can be done in one class, and it is an example of AL.

Keywords: *quiz-creation activity, guess who / where / what quiz, active learning, student-centered class, teacher's role as a facilitator, learning the four skills of English, writing English skill, speaking English skill*

Introduction

The new curriculum guidelines promulgated by the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) indicate that teachers must develop more student-centered classes. Greater attention is being paid to active learning (AL) classes. MEXT suggests that teachers change their teaching styles from making lecture-centered classes to making student-centered ones. Having students create and present presentations in class is often taken as a solution to the problem of AL. MEXT also suggests that English teachers teach the four skills of reading, writing, listening, and speaking equally in their classes. Making a presentation in English is a good means of implementing AL, because it entails that students use all four skills equally in creating and presenting their presentations. That is, they write English sentences for their scripts, listen to their team members' ideas and coordinate, and read from their presentations in English. Further, the students in the audience listen to them. The four skills are studied in this way. However, this activity is not suitable for every type of study. In particular, as teachers explain English grammar, the classes tend to become lecture-centered.

The Grammar-Translation Method has long been used in English classes in Japan. During these lessons, students translate English sentences into Japanese. Here, English grammar is not studied to communicate in English but for reading correctly. One means used to check students' understanding of English grammar in this approach is to have them work out answers to grammatical questions. The student's aim in learning grammar is to obtain a better score on the examinations and tests. Teachers provide students with tips to help them work out the answers to the grammatical questions. This is the traditional approach to instruction in English grammar. Under this regime, students have fewer opportunities to speak English or to communicate their ideas and opinions in English. It is also difficult for teachers to make their classes into a student-centered learning environment while taking this approach. Students thus have fewer opportunities to communicate in English.

It is important and necessary for learners of English to understand its grammar. We need and use grammatical knowledge to communicate in English. In particular, when students are required to write academic papers, they must write English sentences without allowing grammatical mistakes. When students are making their presentations in English as well, they need grammatical knowledge. The point of making improvements to the structure of English lessons is to encourage students to use the English grammar they have acquired in their communication.

This paper suggests a small and simple student-centered activity that can be used even for the study of English grammar. This is a quiz-creation activity that I call "Guess-de-show!" During this activity, teachers can take on another role. They become more facilitators than lecturers. Quiz activities facilitate student's language use. It is more enjoyable to create and provide responses to quizzes than to work out the answers to grammatical questions. This provides students with more opportunities to communicate in English for a short time. It can also function as another way for students to check their understanding of the grammar that is the theme of the lesson. By means of creating a quiz, students improve their ability to write English sentences.

While making a presentation in English is a good exercise and is a goal for the students at my college, it can be difficult for first year students to get used to. The quiz-creation activity forms a small step to acclimatize them to this approach. The goal is for the students to make presentations that they give in English in the third year. The quiz activity takes less time and energy for both teachers and students to prepare for than a presentation in English. The first year students participate easily in this activity, which forms part of lessons throughout the school year. I began with this activity two years ago. This practice report presents my experience of the past two years, examples of the creating-quiz activities, and the growth the students have exhibited in writing English.

Pedagogy

Before beginning the main part of this report, I present the background of the students at Kushiro College. Kushiro students tend to feel that they are not good at English. They have not had sufficient opportunity to communicate in English in their English classes, as they had only been junior high school students. They have less interest in English than in Mathematics and Science. Therefore, I felt that it was difficult to bring AL into teaching English grammar. Most of my students hesitate to write their opinions in English. Likewise, they have difficulty speaking English in front of other students. Taking all of this into account, I set a goal to be concluded in three years. Table 1 shows the three year plan for the development of English writing and communication skills. This year will be the third year of this plan. The third year students will make the presentations about some topics in English at the end of this year.

Table 1: Three year plan for the development of English writing and communication skills

Year	The numbers of words for writing	Students' activity
First year	40 - 60 words	Creating quiz activities
Second year	70 - 90 words	Writing a short essay
Third year	100 - 120 words	Making presentations

This paper is an interim report from the second out of three years. It focuses more on the creating quizzes done during the first year, including discussion of quizzes on the theme of guess who, guess where, and guess what. Table 2 shows the grammar acquired along with the creating-quiz activity.

Table 2: Grammar acquired along with the creating-quiz activity

Example	Grammar acquired	Guess-de-show!
1	Five sentence structures	"Guess who" quiz
2	Auxiliary verbs	"Guess where" quiz
3	The infinitive	"Guess what" quiz

As Table 3 shows, two classes (180 minutes in total) are allotted for each grammar lecture. I divide the 180 minute times assigned to each topic into four sections. The first division is the lecture-centered class (60 minutes), where the students listen to a lecture on the target grammar. The second division is a student-centered class (40 minutes), where the creating-quiz activity is performed. The third division is a student-centered class (20 minutes) in the pair work. Finally, the fourth division (60 minutes) is lecture-centered, where the students work out the answers to the grammatical exercises.

Table 3: Four divisions

Division	Time	Learning style	Students' activity
1	60 min.	Lecture-centered	The lecture of Grammar
2	40 min.	Student-centered	The creating-quiz activity
3	20 min.	Student-centered	Pair work
4	60 min.	Lecture-centered	Practice exercises

An example of this follows. For instance, I give the lecture on five sentence structures (SV, SVC, SVO, SVOO, and SVOC) to the first year students in April. In the first division, I explain the relevant English grammar. This is a lecture-centered class. I use both Japanese and English to explain the target grammar. After the lecture, the students move on to quiz-creation in the second division. This is a student-centered activity. The theme of the quiz is your favorite person. Students must use five sentence structures for their hints about who their favorite person is, giving five hints in English under the following rules. Students must follow the rules of the guess who quiz. That is, they must use the following words and phrases: “lives in …,” “is,” and “one’s occupation is …,” writing more than 40 words in total for the five hints. Table 4 shows an example for the guess who quiz.

Table 4: Example for the “guess who” quiz

No.	Hint
1	He lives in both the U.S.A. and Japan.
2	We call him the two-way player. His occupation is a professional baseball player.
3	He is tall and his smile is so cute.
4	He won the MVP prize 2021.
5	He gave team staff a special bonus.

Guess who? The answer is Ohtani Shohei.

After the students have finished creating hints, the third division begins. This is another student-centered class, where the role of the teacher is to facilitate the students’ quizzes. For example: Student A (Questioner) starts as follows: “I am going to talk about my favorite person. I give you five hints. Guess who!” Student A gives five hints to Student B (Answerer). Student B listens to the hints and writes them down on the sheet. After all of the hints are given, Student B responds with a guess. If Student B wants more information, it is allowed to question Student A in English. After the quiz is complete, Students A and B switch places. In the following round, the students take new partners. After completing the second round, the students move on to the fourth division. Students wrap up the grammar they learned. They work out the answers to grammatical questions to check their understanding. After the students have finished the questions, the teacher explains the answers to the questions. This is a lecture-centered class. I use both Japanese and English for these explanations.

The following presents another example. In this case, I give a lecture on the English auxiliary verbs. After this lecture, students do the creating-quiz activity. Here, the theme of the quiz regards each student’s favorite place. The students must use auxiliary verbs to write five hints in English using the following rules. Students must use at least two auxiliary verbs that they learned in the lecture, tell the location of their favorite place and how to get there, and use the following words and phrases: “is located in …,” “If you go there,” and “is famous for ….” Table 5 presents an example of the guess where quiz.

Table 5: Example of the “guess where” quiz

No.	Hint
1	It is located in Kushiro, a town in eastern Hokkaido, Japan.
2	It takes 90 minutes to get there from the center of Kushiro city by bus.
3	The air in the area is the cleanest in Japan.
4	If you go there, you can enjoy beautiful scenery.
5	It is famous for the lake and moss balls called “Marimo.” You will be able to take a boat.

Guess where? The answer is Lake Akan.

The following is the last example, and it comes with a lecture on the infinitive. Students must use the infinitive to make and write five hints in English. The theme of the quiz is one’s favorite tool. Students must use the infinitive at least once and provide basic information on the tool: its material, color, price, and application, using following words and phrases: “its … is …” and “I use it to do ….” Table 6 shows an example of the guess what quiz.

Table 6: Example for the “guess what” quiz

No.	Hint
1	If you have it, it is very helpful. It is used with only one hand.
2	It can have many materials. Plastic and wood are often used.
3	Its color varies. White, brown, and so on.
4	Its price varies. You can get it at 100-yen shops.
5	If you use it, it is easier for you to put on your shoes smoothly.

Guess what? The answer is a shoehorn. As noted above, students use recently acquired grammar to do this creating-quiz activity. They do this activity 10 times through the year. The more those students become accustomed to this activity, the shorter time they spend preparing for it.

Results and Discussion

I began with this quiz creation approach two years ago. I have had responses from my students regarding both the positive and negative aspects from both students and teachers. The students have appreciated having more opportunities to write, think, and communicate in English, going beyond simply working out the answers to grammatical questions. They have more enjoyment doing the quiz activity than ordinary class work. This helps them to maintain their motivation to communicate in English, and they do not hesitate to use and speak English with each other. On the other hand, among the negative effects for students is that the number of questions that students work on is smaller than ever. In a lecture-centered class, they mainly work on answers to grammatical exercises. They might need more grammatical questions.

This quiz-creation has both positive and negative effects for teachers. One positive effect for teachers is that the quiz-creation is easy to take in and manage. Teachers do not have to think of all teaching materials on their own, as students create their own quizzes. On the other hand, although students certainly spend time writing and communicating in English, teachers cannot check whether each English sentence written for their quiz hints is grammatically correct. Furthermore, it is a worth noting that the pace at which students encounter grammar points is slower with the quiz-creation than in a lecture-centered class.

Tables 7-9 present the growth in students’ writing skills. The same students were tested. The number of students decreased from 2022 to 2023 because some students dropped out of school entirely or were absent on the particular day. Table 7 shows the results of the second-term writing test held in February 2022. Students provided five hints for the guess where quiz. The theme of the quiz was on the students' favorite places. The grammar target was the if-clause. Students used the following phrase: "if you go there, you …." On average, students wrote 38.7 words.

Table 7: Second-term writing test in 2022

Date	2/7/2022
Theme of the quiz	My favorite place
Number of the first-year students tested	137
(a)Average number of words used in the test	43.7 words
(b)Number of required words and phrases	5 words
(c)Actual number of words:(a)-(b)	38.7 words

In the next academic year, the students wrote a short essay and read it to their partner. When they took the writing test during the first term, they wrote a short essay about places of interest for foreign tourists. They spent 90 minutes preparing, including gathering information and writing their script before they told it to the partner. Students had to use the following words and phrases: "the first attractive point," "second," "third," "let me introduce …," "the world with …," and "you will see O do …." As shown in Table 8, the average actual number of words was 70.3 words.

Table 8: First-term writing test in 2022

Date	6/13/2022
Theme of the short essay	Places of interest
Number of the second-year students tested	119
(a)Average number of words used in the test	87.3 words
(b)Number of required words and phrases	17 words
(c)Actual number of words:(a)-(b)	70.3 words

In the second-term writing test, students wrote a short essay on the festival in the world. They spent 90 minutes preparing to gather information, writing their script, and telling it to their partner. Students were required to use the following words and phrases: "let me introduce …," "the festival has many attractions," "first," "second," "third," "the biggest attraction of the festival is …," and "Next time you visit … in …," As shown in Table 9, the average number of words used was 74.4.

Table 9: Second-term writing test in 2023

Date	2/13/2023
Theme of the short essay	World festivals
Number of the second-year students tested	122
(a)Average number of words used in the test	97.4 words
(b)Number of required words and phrases	23 words
(c)Actual number of words:(a)-(b)	74.4 words

As shown in the average number of words used, most students improved their writing ability. This also shows that they had continued to learn English and had sustained their motivation.

Conclusions

This quiz-creation activity is easy to implement in the English grammar classes. Both teachers and students continued doing this activity through the year. This activity helped to eliminate students' hesitation regarding writing and communicating in English. As the data show, this activity forms as a small step toward writing a short essay and improves students' writing skill. This short and enjoyable activity is an example of using AL in an English class.

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Qualitative Analysis of Reflection Sheet in Group Presentation Activities
- A Case Study for Enhancing Cooperative Learning -

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Abstract

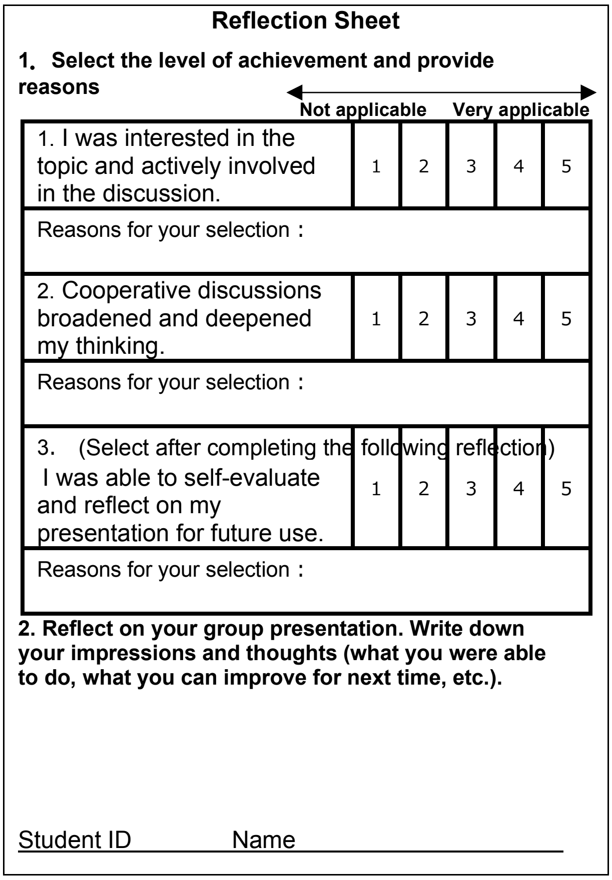
This study examines individual learning and group interaction in our presentation activities to enhance group activities leading to more cooperative learning. We have positioned group presentations as part of the curriculum for the 2020-2022 academic year English classes for third-year students of technical college and have reflected on them with a reflection sheet that we made based on the perspective of "independent, interactive, and deep learning (active learning)" (MEXT, 2017, 2018). From among forty-two groups of the 2022 practice, one presentation group with the highest values for our reflection sheet responses was selected. We analyzed their individual learning and group interaction qualitatively referring to their reflection sheet responses. The following are the results: 1) This group had active interactions and tried to fulfill their responsibility as a group to get all five members together to communicate. We believe this realized "independent, interactive, and deep learning (active learning)" (MEXT, 2017, 2018) and resulted in high values for their reflection sheet responses. The presentation was shared within the group, and everyone was aware of the positive interdependence. 2) Consideration should be given to students who are not fully aware of their specific roles, such as Students D and E. This is because, although they participated in the group discussion, they may not have been aware of their specific roles and responsibilities as individuals. It would be desirable to introduce such roles as "facilitator" and "follower" during discussions, and to devise instruction that allows each participant to recognize his/her own strengths. 3) Only three of the five responses met with the evaluation of the group processing, which suggests that our reflection sheet needs to be improved in this regard. Dividing the free-response section into "reflection as individuals" and "reflection as a group" will let the participants analyze the group activity itself. Reflection during the preparation phase could also facilitate or modify the group interaction.

Keywords: *group presentation, cooperative learning, qualitative analysis, reflection, interaction*

Introduction

Presentation is an activity to convey one's thoughts, ideas, and facts based on a certain theme, utilizing data and evidence (Takizawa, 2021). The authors' school has been implementing group or individual presentation activities in English classes since 2017 (Shinomura, Hattori, & Harvey, 2020). We have positioned group presentations as part of the curriculum for the 2020-2022 academic year English classes for third-year students of technical college and have reflected on them with a reflection sheet (Table 1) based on the perspective of "independent, interactive, and deep learning (active learning)" (MEXT, 2017, 2018). We examine our students' individual learning and group interaction to enhance group activities for more cooperative learning.

Table 1: Reflection sheet



Reflection Sheet

1. Select the level of achievement and provide reasons

Not applicable ↔ Very applicable

1. I was interested in the topic and actively involved in the discussion.	1	2	3	4	5
Reasons for your selection：					
2. Cooperative discussions broadened and deepened my thinking.	1	2	3	4	5
Reasons for your selection：					
3. (Select after completing the following reflection) I was able to self-evaluate and reflect on my presentation for future use.	1	2	3	4	5
Reasons for your selection：					

2. Reflect on your group presentation. Write down your impressions and thoughts (what you were able to do, what you can improve for next time, etc.).

Student ID Name

Previous research and Research question

Cooperative learning is defined as “the instructional use of small groups so that students work together to maximize their own and each other’s learning” (Johnson, Johnson, & Holubec, 1993, p.6). Sugie (2022) emphasizes the difference in the goals that members of a group aim for: Competition aims for pecking order among peers, while Cooperation aims for growth of all peers. Cooperative learning leads to career education because it develops leaders and followers through role learning (Umemura, 2015), and full / partial class work reforms incorporating cooperative learning are spreading rapidly (Sato, 2023).

Our presentation groups are organized so that students' English proficiency is evenly distributed as Kagan & Kagan (2015) recommends, and there is a considerable difference in English proficiency among group members. Meanwhile, Machi and Nakaya (2013) reports that if the academic differences among group members in cooperative learning are too large, it is difficult to generate intragroup interaction. This also led us to believe that the interactions within our presentation groups need to be examined.

“For cooperation to work well teachers explicitly have to structure five essential elements in each lesson” (Johnson et al.,1993, p.9). These five essential elements are in Table 2, excerpted and tabulated by the authors. We examine individual learning and group interaction of our presentation group in the light of Table 2.

Table 2: Five essential elements

1) Positive interdependence	Group members must perceive that they are linked with each other in a way that one cannot succeed unless everyone succeeds.
2) Individual and Group accountability	Group must be accountable for achieving its goals, and each member must be accountable for contributing his or her share of the work.
3) Promotive interaction, preferably face-to-face	Students need to do real work together in which they promote each other’s success by sharing resources and helping, supporting, encouraging, and praising each other’s efforts to learn.
4) Teaching students the required interpersonal and small group skills	Students are required to learn academic subject matter (taskwork) and also to learn the interpersonal and small group skills required to function as part of a group (teamwork).
5) Group processing	Groups need to describe what member actions are helpful and unhelpful and make decisions about what behaviors to continue or change.

Note: Johnson et al. (1993, pp.9-11), excerpted and tabulated by the authors

Course Outline

Our group presentation is to achieve one of the six objectives of the third-year students’ English course (2 credits; 90 min. x 30 sessions): “To be able to give a presentation on an everyday or social topic with audience in mind.” Guidance / group activities (30 min. x five times) and rehearsal / performance (90 min. x twice) are allocated for group presentation (Table 3). Presentation handout (Table 4) and evaluation rubric (Table 5) are handed to the students at the beginning of this activity. The manuscript was written in English by each member and submitted as a group, with feedback given once to the group to ensure that the content was consistent with the theme.

Table 3: Allocation for group presentation activities of the English course

Sessions	1	2	3	4	5	6	7	8	9	10
Date	4/8	4/12	4/19	4/22	4/26	5/6	5/10	**5/13**	5/17	**5/20**
Time								**30m**		**30m**
Sessions	11	12	13	14	15	16	17	18	19	20
Date	5/24	**5/27**	5/31	**6/3**	6/7	6/10	6/14	**exam**	**6/21**	6/24
Time		**30m**		**30m**					**30m**	
Sessions	21	22	23	24	25	26	27	28	29	30
Date	**6/28**	7/5	**7/8**	7/11	7/15	7/22	7/26	**exam**	8/9	8/12
Time	**90m**		**90m**							

Table 4: Presentation handout

Group Presentation Theme:

"Let's compare "something" between Japan and the world (or a certain country) with Diversity and Inclusion in mind

1. **Outline**

Decide on a topic as a group. Be sure to include things that are professional and meaningful to the audience. Use reliable (unbiased, objective) data and information and clearly indicate source information. Conducting a survey could make the presentation more effective.

2. **Important Dates**

Deadline of Manuscript: May 31st
Deadline of Slides: June 28th
Presentation: July 8th

3. **Guideline for the structure of the presentations**

Each person should present for approx. 1 min. Create a coherent manuscript. Choose vocabulary that is easy to listen to and understand. The word count is "about 100-120 words per person".

Introduction	• State your general topic • Orient the audience to your subject and purpose.
Body 1	• Develop and sum up each point. • Provide supporting data and materials. • Comparison requires the same conditions.
Body 2	
Body 3	
Conclusion	• Remind the audience again of the topic. • Remind the audience of your argument and findings.

Topic Example：

Eating habits, communication, onomatopoeia, school, extracurricular activities, sports, Pop Culture, drama, entertainment, living environment, smartphones, SNS, coronavirus, land, climate, environmental issues, disasters, plastics, energy, infrastructure, public transportation, birth rate, death rate, low birthrate, aging population, income, cashless, telework, working hours, men's childcare leave, employment of people with disabilities, …

Table 5: Evaluation rubric

Presentation Evaluation Sheet

EVALUATION CRITERIA

	Content	English		Delivery
	valuable material beneficial	pronunciation and intonation	fluency	presentation from the audience's perspective
3		Good pronunciation and intonation, easy to understand.	Appropriate pauses and natural speed, easy to understand.	
2	Presentation had a good amount of valuable material and beneficial to the audience.	Katakana English in places, but generally good pronunciation and intonation.	Stuck in places, but generally natural speed.	Good verbal / non-verbal language (pauses, use of materials, etc.).
1	Presentation had some valuable material, but content was lacking.	Katakana English and misread in places, but the meaning was mostly conveyed.	Inappropriate pauses and stuck in places, but the meaning was mostly conveyed.	Improvements for better presentation: □ Louder Voice □ Eye Contact □ Pauses □ Questioning / Storytelling □ Visual Aids □ Posture □ Facial expression
0	Presentation had very little valuable material.	Katakana English or incorrect pronunciation and intonation did not convey the meaning.	Inappropriate pauses and stuck in places did not convey the meaning.	Failure to give a good presentation from the audience's point of view (pauses, use of materials)

Group# Student ID Name

Subjects and Methods

The survey was conducted on forty-two groups (203 students) by having them answer our reflection sheet (Table 1) immediately after their group presentation performance (held on July 8, 2022). One presentation group with the highest values for the reflection sheet responses was selected as the target group (five subjects; Table 6,7), and we decided to perform a qualitative analysis on the data of them. The purpose of the survey was explained to the five subjects and their consent to cooperate in the survey was obtained.

Table 6: Five subjects' responses on the reflection sheet

Survey Questions	Selected Five subjects					Surveyed 203 students	
	A	B	C	D	E	AVE	SD
1. I was interested in the topic and actively involved in the discussion.	5	5	5	5	2	4.1	0.86
2. Cooperative discussions broadened and deepened my thinking	5	5	5	4	5	4.0	0.91
3. I was able to self-evaluate and reflect on my presentation for future use	5	5	5	5	5	4.2	0.89

Table 7: Five subjects' background

Subjects	A	B	C	D	E
TOEIC Jan. 2023	525	315	275	290	330
Learning English	Very active	active	Not very active	Not very active	Not very active
School Life	Very positive	positive	positive	Very positive	positive

Results and Discussion

Subjects are named A, B, C, D, and E in the order of their performance on the evaluation rubric (Table 5). We analyze and discuss Student A, B, C, D, and E's reflection sheet responses (Table 8-12: the students' responses were in Japanese, translated into English and underlined by the authors) in the light of Table 2.

Table 8: Student A's response

1. I was interested in the topic and actively involved in the discussion.	1	2	3	4	⑤
Reasons for your selection : I prepared my speech manuscript while thinking about which materials to use.					
2. Cooperative discussions broadened and deepened my thinking	1	2	3	4	⑤
Reasons for your selection : Instead of dividing up the work, we discussed all manuscripts and slides together. By doing so, I was able to listen to each person's knowledge and ideas, which deepened my own thinking.					
3. (Select after completing the following reflection.) I was able to self-evaluate and reflect on my presentation for future use	1	2	3	4	⑤
Reasons for your selection : By listing the good and bad points of my presentation, I was able to clarify what I should pay attention to in my future presentation.					
Reflect on your presentation					
I am glad I was able to memorize the manuscript and present it. I made my presentation while pointing to the material on the slides. This probably made it easier for the audience to understand the presentation. But I spoke a little too fast, so next time I want to be conscious of speaking slowly when I speak in public. When writing the manuscript, I used a lot of junior high school English grammar and simple words to convey the message as easily as possible, so it was easy to memorize. We found that writing a manuscript that was easy for our audience to understand made it easier for us to present our work. I was able to complete the manuscript even though I used almost exclusively junior high school English grammar. That allowed me to reaffirm how important junior high school English grammar is. When I looked up vocabulary in preparing my manuscript, I found quite a few words I didn't know, so I wanted to learn more words and strengthen my English skills.					

Instead of dividing up the work, we discussed all manuscripts and slides together. By doing so, I was able to listen to each person's knowledge and ideas, which deepened my own thinking. This indicates that this group all gathered together to prepare manuscripts and slides, helping with each other (Table 2-1,2,4). In that process, Student A exchanged his/her idea with other members (Table 2-3) and favorably evaluated the way that proceeded (Table 2-5). I was able to memorize the manuscript and present it. I made my presentation while pointing to the material on the slides. This shows that Student A is satisfied with his/her presentation partly because When writing the manuscript, I used a lot of junior high school English grammar and simple words to convey the message as easily as possible. (Table 2-2,5). This point is shared with the group members, as Student D says our manuscript was easy for everybody to understand (Table 11) and Student E says we were expected to use as simple a word as possible (Table 12), indicating a lot of face-to-face communication (Table 2-3) and Student A's supportive attitude toward other members (Table 2-2,4). According to an informal exchange between Student A and the author a few days after the presentation, Student C offered to be in charge of the slides and Student B offered to make the graphs in the map book easier to read on the graphing website. Student A appreciates his/her learning as an individual through preparing his/her own speech manuscript, reaffirms how important junior high school English grammar is, and also plans future studies: I found quite a few words I didn't know, so I wanted to learn more words and strengthen my English skills.

Table 9: Student B's response

1. I was interested in the topic and actively involved in the discussion.	1	2	3	4	⑤
Reasons for your selection : For myself, I considered where to get materials and which data would be effective for the topic decided by the group.					
2. Cooperative discussions broadened and deepened my thinking	1	2	3	4	⑤
Reasons for your selection : Throughout the entire process, we worked together to complete the presentation, with rough division of roles.					
3. (Select after completing the following reflection.) I was able to self-evaluate and reflect on my presentation for future use	1	2	3	4	⑤
Reasons for your selection : I identified and reflected on what was good and what was bad.					
Reflect on your presentation					
We roughly divided the roles as follows: manuscript, PPT, and graphs; and all members checked and completed each of them. I believe that this process helped us to create high-quality presentation materials. I practiced so that I could present my presentation smoothly, but I was disappointed that I could not say it as smoothly in the actual performance as I did in practice. I missed the timing of the slide changeover during the presentation. I must be careful in my future presentations.					

For myself, I considered where to get materials and which materials would be effective. This indicates that Student B was primarily involved in the search and selection of materials (Table 2-2). We roughly divided the roles as follows: manuscript, PPT, and graphs; and all members checked and completed each of them. I believe that this process helped us to create high-quality presentation materials. This statement suggests that certain students were primarily involved in the manuscript, PPT, and graphs, as Student A stated, and that Student B appreciated the contributions of those students (Table 2-2). Student B also favorably evaluates the interaction of the group that finished it all together (Table 2-1,3,4,5). Student B was satisfied with the material prepared by the entire group, but reflecting on his/her individual performance, Student B was disappointed that I could not say it as smoothly in the actual performance as I had done in practice.

Table 10: Student C's Response

1. I was interested in the topic and actively involved in the discussion.	1	2	3	4	⑤
Reasons for your selection : I was originally interested in trade, which supports the world's economy, and the topography and climate that affect that trade.					
2. Cooperative discussions broadened and deepened my thinking	1	2	3	4	⑤
Reasons for your selection : In producing the manuscript, we gathered a variety of data and facts and discussed them with each other. This helped us to deepen our understanding and knowledge of the topic.					
3. (Select after completing the following reflection.) I was able to self-evaluate and reflect on my presentation for future use	1	2	3	4	⑤
Reasons for your selection : Reflecting on the practice allowed us to think about how we can apply the experience to the next step.					
Reflect on your presentation					
This time, I was mainly in charge of the manuscript and slides. In the beginning, I relied on my friends to help me write the manuscript because my vocabulary was poor, and my grammar was messed up. However, as I worked on the manuscript, my English and writing skills gradually improved, and I learned to write English smoothly. I did a lot of work in making slides. Focusing on clarity, we used Yu Gothic so that the text would be easy to read from a distance. I also reduced unnecessary animations.					

I was originally interested in trade, which supports the world's economy, and the topography and climate that affect that trade. This and Student B's statement the topic decided by the group (Table 9) indicate that this group's topic (Geographical Condition and Trade) reflects the interests of Student C and the other members agreed with Student C's proposal (Table 2-3,4). Focusing on clarity, we used Yu Gothic so that the text would be easy to read from a distance. I also reduced unnecessary animations. This shows that student B is accountable for contributing his/her share of the work, and feels a sense of accomplishment (Table 2-1,2). As for manuscript, student C relied on his/her friends at first, but as I worked on the manuscript, my English and writing skills gradually improved, and I learned to write smoothly, which inferrs that there was promotive interaction within the group (Table 2-3). When the evaluation rubrics (Table 5) were handed to each student, Student C was relieved to learn of Student A's good evaluation. This indicates a positive interdependence, that is, Student C is aware that his/her efforts are linked to Student A's grade (Table 2-1).

Table 11: Student D's Response

1. I was interested in the topic and actively involved in the discussion.	1	2	3	4	⑤
Reasons for your selection : Instead of using a machine translation app, I wrote my manuscript using words and grammar I knew, based on map books and other sources. We were actively engaged in this project outside of class time, too.					
2. Cooperative discussions broadened and deepened my thinking	1	2	3	④	5
Reasons for your selection : Whenever possible, we communicated face-to-face as we prepared and practiced. We divided up the work and most of us were responsible for our own tasks. I missed a few of the meetings for my club practice.					
3. (Select after completing the following reflection.) I was able to self-evaluate and reflect on my presentation for future use	1	2	3	4	⑤
Reasons for your selection : I figured out what I could do and could not do in this presentation.					
Reflect on your presentation					
I should have practiced more so that I could present with confidence. In the actual performance, all the text that I had memorized had gone and I just read it. I could not deliver my message with gestures though I had practiced. Good things were that our slide did not include any Japanese word, that our manuscript was easy for everybody to understand, that we created a graph using a chart in a map book, and that we shared and exchanged our ideas by LINE app during individual work. It was a pity I could not present smoothly. This was partly because I did not practice using slides very often.					

Instead of using a machine translation app, I wrote my manuscript using words and grammar I knew, which indicates that Student D focused on the manuscript (Table 2-2). We were actively engaged in this project outside of class time, too, Whenever possible, we communicated face-to-face as we prepared and practiced, and I missed a few of the meetings for my club practice indicate that this group had promotive interaction outside the class time (Table 2-3), and that Student D is accountable for attending the group meeting to achieve their goal (Table 2-1,2). We divided up the work and most of us were responsible for our own tasks shows that the work was divided up to some extent and was checked and completed through face-to-face communication (Table 2-3,4). Good things were that our slide did not include any Japanese word, that our manuscript was easy for everybody to understand, that we created a graph using a chart in a map book, and that we shared and exchanged our ideas by LINE app during individual work. These show that Student D is supporting and praising each other's efforts to learn (Table 2-3,5), but reflecting on his/her individual performance, Student D regrets that s/he did not practice using slides very often. And there is no remark about his/her indivudual accountability.

Table 12: Student E's Response

1. I was interested in the topic and actively involved in the discussion.	1	②	3	4	5
Reasons for your selection : I relied on my friends too much and was not involved in the discussion.					
2. Cooperative discussions broadened and deepened my thinking	1	2	3	4	⑤
Reasons for your selection : Our group all got together often to have face-to-face communication. Through the discussion I was able to deepen my understanding the topic.					
3. (Select after completing the following reflection.) I was able to self-evaluate and reflect on my presentation for future use	1	2	3	4	⑤
Reasons for your selection : I reflected on my presentation and now I know what I should do in my future presentation. I'm sure I can make better presentation next time.					
Reflect on your presentation					
The presentation had to be easy for the audience to understand, so we were expected to use as simple a word as possible and to make clear slides with appropriate colors and fonts. This took more time than I had expected. I'd like to make better presentation by making easy-to-understand manuscript and brushing up my skill of making slides.					

Despite the statement I relied on my friends too much and was not involved in the discussion, Student E seems to have been involved with group discussion as Our group all got together often to have face-to-face communication. Through the discussion I was able to deepen my understanding the topic. (Table 2-1,2,3). The presentation had to be easy for the audience to understand, so we were expected to use as simple a word as possible and to make clear slides with appropriate colors and fonts. This shows that the important points for making good presentation was shared with the group (Table 2-3). Student E learned that This took more time than I had expected, which also indicates that Student E's close involvement with this group work (Table 2-3). Student E, too, did not remark anything about his indivudual accountability, but s/he stated I'd like to make better presentation by making easy-to-understand manuscript and brushing up my skill of making slides, looking ahead to future presentations.

Conclusions

We examined individual learning and group interaction in our presentation activities qualitatively referring to one presentation group’s reflection sheet responses. Our discussion can be summarized in the following three points and Table 13, from the perspective of cooperative learning, in the light of Johnson et al. (1993)’s five essential elements (Table 2).

The first point is that the target group had active communication and tried to fulfill their responsibility as a group to get all five members together to communicate. We believe this realized "independent, interactive, and deep learning (active learning)" (MEXT, 2017, 2018) and that this resulted in the high values for the reflection sheet responses. The key points of the presentation are shared within the group, and everyone was aware of the positive interdependence.

The second point is that consideration should be given to students who are not fully aware of their specific roles, such as Students D and E. Student A was mainly responsible for the manuscript, Student B for the graphs, Student C for the slide, but Student D and E did not have specific names for the roles they focused on. It would be desirable to introduce such roles as "facilitator" and "follower" during discussions, and to devise instruction that allows each participant to recognize his/her own strengths while recognizing these roles.

The third point is that only three out of five responses met group processing (Table 13-5), indicating that our reflection sheet (Table 1) needs to be improved. By modifying the form, it is possible to have the participants describe their "reflections as individuals" and "reflections as a group" and let them reflect on their group activity itself. Moreover, by conducting such reflections during the preparation phase, the students could facilitate or modify the group interaction.

Table 13: Summary of our discussion

Five essential elements	Student				
	A	B	C	D	E
1) Positive interdependence	○	○	○	○	○
2) Individual and Group accountability	○	○	○	△	△
3) Promotive interaction, preferably face-to-face	○	○	○	○	○
4) Teaching students the required interpersonal and small group skills	○	○	○	○	
5) Group processing	○	○		○	

Note 1: Johnson et al. (1993, pp.9-11)

Note 2: ○ shows that the student’s learning met that element; and △, partly met that element.

It is difficult to generalize the results of this study because it is a case study of the only one group (five subjects). Although we have not considered the factors in detail that determine interaction, such as each subject's characteristics and learning tasks, the actual learning and group interaction had the characteristics described above. We would like to analyze the reality of the interaction in more detail by interviewing these subjects.

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ONLINE TEAROOM DESIGN INTERNATIONAL WORKSHOP: NEW CHALLENGES

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Abstract

Akashi College Architecture Department offered online international design workshops to replace the international exchange activities suspended due to the COVID-19 pandemic.

The first online design workshop started in November 2020 and ended in January 2021. It had 53 participants, including students from Japan, Brazil, Hong Kong, Indonesia, and Singapore. The second online design workshop started in October 2021 and ended in January 2022. It had 90 participants: 84 students from Japan, Brazil, Hong Kong, Germany, the Philippines, and Mexico, and 6 Taiwanese teachers from six different Kaohsiung municipal technical high schools. The third workshop started in November 2022 and ended in February 2023. It had 50 participants, including students from Japan, Brazil, Hong Kong, and Germany. All workshops had once a week an online meeting session of 90 minutes. The students worked in groups and developed a design for a tearoom. At the end of the workshop, they explained their design using drawings and a five-minute video presentation. These workshops were part of an elective course for Japanese students, and they worked together in the same room while having online meetings with their international group members. Two instructors monitored the online sessions and assisted the students when necessary.

This paper offers practical teaching suggestions by comparing the results from three workshops. The action research methodology was used to evaluate the workshops, diagnose the problems, and implement solutions. The diagnosis was made through interviews and observation of the students during the workshop and post-workshop surveys. Also, the product of the workshops, the tearoom designs developed by the students, are analyzed and compared. First, we explain how the workshops, from the recruitment of the students to the final presentation. We present difficulties and troubles experienced during each workshop. Later, we will compare the products of the workshops and the tearoom designs of the online workshop with the previous offline workshop.

Keywords: *online design workshop, international exchange, tearoom, traditional Japanese architecture*

Introduction

Architectural practice is a global profession, and architecture students must be prepared to work in a multicultural environment. In a country such as Japan, with a culturally homogeneous society and few immigrants, internationalizing the educational environment goes beyond improving the student's knowledge of English.

How do we prepare Japanese students to work in a multicultural context through studio teaching?

The idea was simple: organize a design workshop, invite students from abroad, and have them work with our students on an architectural design. We organized a 3-week Japanese architecture internship program with lectures, field trips, workshops, and, as the main event, the tearoom design workshop.

The first tearoom design workshop was in 2015, and the last was in January 2020. During the first design workshops, there were several problems and miscommunication between the students. The design workshops showed that communication between the students also involved understating social rules with a strong cultural background. Japanese students expected the international students to act according to rules that the international students were not familiar with, resulting in angry students from both sides. (Dupre,2018) However, this problem was solved over time. Through interaction with international students, Japanese students learned to accept international students' behavior and communicate with people from different cultural backgrounds. (Higashino,2019)

Unfortunately, due to the COVID-19 pandemic, academic activities that involved traveling abroad or receiving international students had to be canceled. It was impossible to accept international students, so we decided to hold the design workshop online.

The idea of an online design workshop is older than the pandemic. The Japanese architecture internship program had few international participants, mainly because of the costs of coming to Japan. Therefore, if some of the activities were online, more international students could participate, resulting in more exposition of Japanese students in a global context. However, before the pandemic to organize an online workshop was complicated. There was a lack of tools and interest of the students. (Higashino, 2018)

The first online design workshop started in November 2020 and ended in January 2021. The second workshop started in October 2021 and ended in January 2021. The third workshop began in November 2022 and ended in February 2023.

Materials and Methodology

In this research, we used the action research method, which understands teaching as a research method through experience, reflection, and practice. The method consists of reflection based on the diagnosis process of the teaching experience.

The action research method has three steps:
1st is to detect and diagnose the problem.
2nd, elaborate a plan to solve the problem, apply it, and collect the results.
3rd is to analyze the results and feedback that will lead back to the 1st step, and a new diagnosis and process of reflection and action occur. (Elliot,1991)

The workshops were project-based, and the instructors defined the final product, the format, and the design process. The main goal of the workshops is the interaction between the students, and the quality of the final product is secondary.

During the workshops, we collected the material to diagnose and solve problems as quickly as possible. This material consists of interviews with the students and surveys at the end of each workshop. The interviews with the Japanese students happened face to face, while for the international students, the interviews were through Zoom or Facebook chat. We also did a photography record of the students during the workshop and took screenshots of their interactions on Facebook. This material was collected during each of the workshops and helped reflect and diagnose problems. The workshop schedule was kept flexible, and the deadlines were adjusted as necessary.

The Online Tearoom Workshop

The workshop can be divided into 3 phases. The 1st phase consists of gathering international students to participate in the workshop dividing and organizing the students into groups. The 2nd phase is the longest, where the students work together and develop a design for a tearoom. The 3rd phase is the presentation of the final product.

To gather international students to participate in the workshop, we posted on the school website and sent a flyer explaining the workshop activities to our partners' schools. As the survey showed (Fig.1), most of the international students joined the workshop because it was recommended by their teachers. In the first year, 2021, the international participants were students from Brazil (UFRGS), Hong Kong (IVE Tsing Yi), Singapore (Nanyang Polytechnic), and Indonesia (Diponegoro University). In the second year,2022, there were students from Brazil, Hong Kong, the Philippines, Mexico (De La Salle University Integrated School), Taiwan (Kaohsiung Municipal Technical High Schools), and Germany (Augsburg University of Applied Sciences). The international students work together with Akashi College 4th-year architecture students. According to the international students' survey, most of them joined the workshop because they wanted to learn about Japanese Architecture and culture, learn about architectural design, interact with people from other countries, and practice English. In the second year, some students said that friends who participated in the previous year's workshop recommended it.

The workshop was conducted on an SNS platform and used Facebook for exchanging data and Zoom for online meetings. We could not use any LMS platform, such as Google Classroom and Microsoft Teams, because the National Institute of Technology cyber security does not allow us to invite people from outside the institution. First, we created a closed group on Facebook and added all the workshop participants to this group. In all three years of the workshop, some students did not have a Facebook account and had trouble joining the group.

After all the students were in the Facebook group, we divided them into smaller groups. The main group was used for transmitting information about Japanese architecture, with lectures and recommended literacy, and to inform on the workshop schedule changes. The smaller Facebook groups were used for exchanging design ideas and developing the tearoom design. The tutors monitored the Facebook group pages and advised the students when necessary.

In the first online meeting (Zoom), we explained the workshop's goals and how the students should develop and present their designs. Also, during the meeting, each student made a short self-introduction. The session was recorded and later posted on the main Facebook page.

The students had to elaborate the design concept and develop it into the design for the tearoom. They have to explain their design ideas using drawings, CG, and models. They also had to make boards with drawings and a final video presentation explaining the design of their tearoom and post it on the main Facebook group page.

Adriana Higashino
Admin · November 4, 2020

Okoshie: tearoom paper models
This is the link to download a paper model of the teahouse Konichian
https://drive.google.com/.../19tooapl5Laq...

It was arranged to print on A3 or A4 size, cut and glue it together.
After you assemble it please share the pictures here!

Student
Its reali a fun way to understand tea house through making the model

Student

Figure 1: Tearoom paper model assignment and student Reaction, Facebook group page screenshot.

In addition, the instructors also posted video lectures about Traditional Japanese architecture to help the international students understand a bit of traditional Japanese Architecture. The Japanese students also researched contemporary tearoom examples and posted them on Facebook.

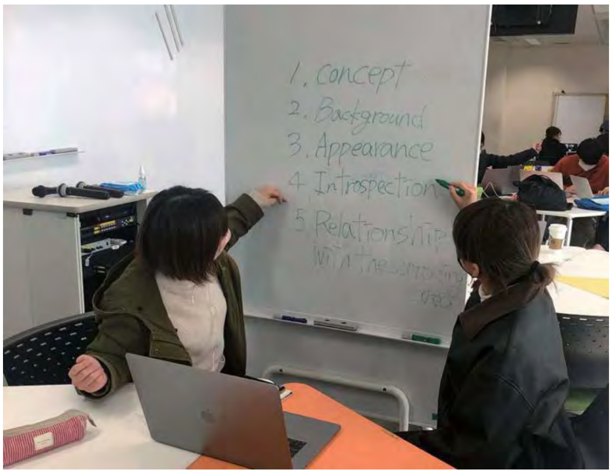
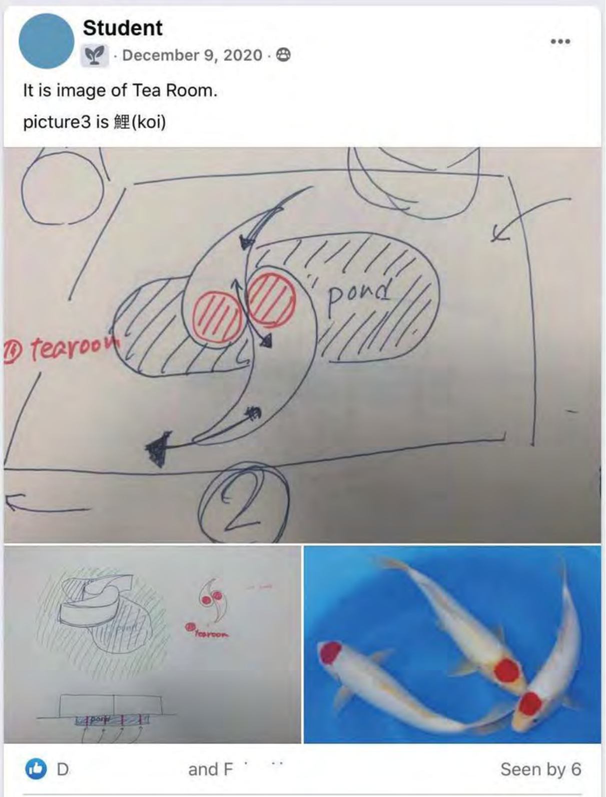


Figure 2: Photo of the students discussing their design concept.

Disconnection and miscommunication were the main troubles during the workshop; overcoming those obstacles was the workshop's primary goal. We explained to them that this was also part of the experience. Some students understood, and others did not. None of the participants were native English speakers, and communication was difficult. However, as one student commented, "It was funny to have some members talking Japanese or Portuguese and translating with drawings."



Student
· December 9, 2020 ·

It is image of Tea Room.
picture3 is 鯉(koi)

D and F

Seen by 6

Figure 3: screenshot of a Facebook group page showing how the students interact and share their ideas.

Troubles and Obstacles

Apart from some students' difficult communication and low English level, the biggest obstacle during the workshop was the time difference and Akashi College's bad internet connection. The workshop is part of a 4th-year elective course for the Architecture major, and the online workshop sessions had to happen during the course classes schedule, which was 10:40 am Japan standard time. The time difference was tough on the students from Germany, who had to join the workshop at 3 a.m.

In the first year, the workshop was on a Wednesday, and we had no significant problems with the internet connection. However, the workshop was on a Monday in the second and third years. That is when we realized that Monday is not a good day of the week for online workshops. First, the school internet was down several times, and we had to postpone the meetings. Most of the repair work in the school happens during the weekend. Every time they need to turn off the electricity, the school server goes down, and on Monday morning, it is not back yet. Also, as a student from Brazil pointed "The lessons were good, but Sunday night, it's hard to maintain focus."

Table1: Number of students in the Workshop

year	Application Form	Conclusion Form	concluded workshop
2020	30	26	87%
2021	65	44	67%
2022	29	16	55%

Table 1 compares the number of international students who answered the application form to those who answered the conclusion form. As the table shows, many of the international students did not finish the workshop. The number of international students who gave up in the middle of the workshop increased over the year. In the second year, we even had to rearrange the groups because there were groups with only two members left.

Why did so many students quit?

In the second year, 2021, the tutors taught that so many international students quit because there were too many participants and too many groups for the two tutors to accessorize. While in the first year, the Japanese students worked together in the same room, in the second year, we had to split them into two rooms, which made it difficult for the teachers to help the students. Also, some groups of the 2021 workshop refused to use Facebook to share and develop their ideas, which made it more complicated for the tutors to advise them along the design process.

Based on the 2021 workshop experience, in the next year's workshop, the number of groups was limited to 10. And the students were forced to post their design process ideas on Facebook. Unfortunately, those were not the only reasons international students quit the workshop, and on the 3rd workshop of 2022, half of the international students who applied did not finish.

Figure 4: Comparison of the student's works

Through the interview with some of these international students, we learned that there were basically 2 reasons for them to quit. The main reason was that the pandemic was over, and the offline classes restarted. Some students from Brazil said they were too busy with university and could not continue participating in the workshop. Some international students complained about our school internet's bad connection, and the sudden cancellation of the workshop sessions was also a reason for them to quit. For students from Brazil and Germany who had to stay awake until late at night to participate in the workshop, it was no fun to have the meeting canceled.

Results and Discussion

After the workshop, the students answered a survey to help us evaluate the workshops. Many of the international students were at the beginning of the Architecture course and did not have much experience with architectural planning or drawing. The feedback from the students was, in general, positive.

When asked if the workshop was up to their expectations, most of the students answered that they were satisfied with the workshop, and there was no student unsatisfied with the workshop.

Regarding communication tools, in 2020, some students were not familiar with Facebook and ZOOM, but thanks to the pandemic and online classes, by 2022, all students were used to the online tools. In addition to Facebook and ZOOM, the students also used other SNS platforms to communicate, such as Line, Instagram, and WhatsApp. As the survey showed, all students met outside the workshop meeting date.

Concerning the division of tasks, all students equally participated in the design process. Most international students executed the computer drawings and 3D computer models, while the Japanese students made the architectural models. Most of the students answered that they were satisfied with the tearoom they designed and what they produced during the workshop. In the first workshop, we allowed the students from Brazil to pair with friends, and we ended up with groups that only had 1st-year students, while in other groups, the students were more advanced in the course and had better architecture presentation skills. Figure 4 shows that on the works of the students from the 2021 workshop, there were groups with students at the end of the Architecture course and amazing drawing and CG skills, while other groups had first-year students drawing for the first time. From 2022, in the 2nd and 3rd workshops, we tried to mix students at different stages of the architecture course, and that resulted in less difference between the student's presentation skills (Fig4. 2022, 2023)

Figure 4 chart compares the students' tearoom, the workshops' product since the first (face-to-face) workshop and the last 3 online workshops. Over the years, we can see fewer hand drawings and more CG drawings made with AutoCAD.

In both types of workshops, offline and online workshop, the students' works showed some common elements:

1)The design of the path to the tearoom, and in this path, a series of events happen.
2)Underground space.
3)The use of a 4 and 1/2 tatami mats floor plan.
4) Various 4 and 1/2 mat floor plans combined.
5) The elaboration of a concept for the tea space.
4) A formal approach and disconnection of the design with the tearoom theme.

The comparison of the students' works shows the there is no difference between the quality of the product from the two types of workshops. Two students that participate on both types of workshops said that they were surprised that they could work online with international students and that the online workshop was much more interesting them they expected. However, they said that in the offline workshops they could establish a more intimate relation with their group's members. According to them in the online workshop they had the chance to interact with a bigger number of international students, but in the off-line workshop this interaction was more intense.

Conclusions

The tearoom design workshop was a positive experience for the students in its offline and online editions. All groups developed a design concept and explained their ideas using drawings, CG, and models. Some groups had difficulty communicating, and the instructors had to give them some support. When the design workshop is online, the students need more time to discuss and develop their ideas than a face-to-face workshop. However, the online workshop allowed low-income students to participate in international exchange activities. During the pandemic, online design workshop was very popular, especially among students from Brazil, but as life went back to normal, it became more difficult to gather participants for the workshop.

The instructors were satisfied with the results, and we intend to repeat the online design workshop. The next step is to try to have a hybrid version, where the students start the workshop online and finish face-to-face in Akashi.

Acknowledgments

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http://www.akashi.ac.jp/news/2020/o7en060000002yi3.html

National Institute of Technology, (KOSEN), Akashi College home page 2021workshop
https://www.akashi.ac.jp/news/2021/20220221arc001.html

National Institute of Technology, (KOSEN), Akashi College home page 2022 workshop
https://www.akashi.ac.jp/news/2022/20230301arc001.html

Students video presentation channel

Videos of 2020 workshop
https://www.youtube.com/playlist?list=PLkMmRzT1WS1YYWocW5hFHwsU-eBgEa-lD

Videos of 2021 workshop
https://www.youtube.com/playlist?list=PLkMmRzT1WS1aq224wjy2Ul5-BSU4ZM_1W

Videos of 2022 workshop
https://www.youtube.com/playlist?list=PLxat57oO1e3PiG44Wzmg9_GWYF-3GWwf-

Developing an Effective Format for Introducing 3D Computer Animation to Adult Learners

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Abstract

By 2030, the workforce in Singapore will be required to transition towards Industry 4.0 which will necessitate the presence of individuals within the force with proficiency in 3D modeling as one of the critical skills to acquire due to its highly transferable nature, applicable across a wide range of sectors (SkillsFuture, 2022). The purpose of this research is to develop a format for teaching basic and intermediate 3D modeling skills within the 3D computer animation context. The research will consider the unique challenges faced by adult learners in this field, such as spanning a broad range of experience or technical knowledge. The SkillsFuture learning platform will be used to deliver this course as it provides accessible learning to Singaporean residents, subsidized for citizens and PR. In addition, the software Blender will be utilized to teach high-end computer animation, a powerful 3D creation software that is free and open source, making it an effective tool for adult learners. The development of three SkillsFuture courses for high-end computer animation was completed and released during the 2021/2022 period, and a total of 11 runs were conducted. The format used was in-person and small size classes which allowed personalized support and to alter the pace of the class according to the learners needs. Furthermore, microlearning (Boring & Tomei, 2022), project-based learning (Pusztai, 2021), and storytelling (Bonds, 2016) andragogy were implemented. The courses were well-received by adult learners spanning a broad range of ages and professional backgrounds and the feedback collected was overwhelmingly positive, confirming they were able to absorb and apply the knowledge imparted. The success of the courses suggests that this format can be used effectively to teach adult learners 3D modelling within the broader context of 3D computer animation. This could lead to the development of more specialized courses for learners who have already completed the introductory courses, providing them with advanced knowledge in the field.

Keywords: *Andragogy, Industry 4.0, 3D Computer Animation, Microlearning, Project-Based, Storytelling.*

Introduction

The Fourth Industrial Revolution (4IR), also known as Industry 4.0, is one of the major drivers of change today. Many believe that it will have a greater impact on the globe than the first industrial revolution did (Donzelli, 2019). According to Temasek Holdings Limited, (2017), up to 375 million individuals worldwide will have to start new occupations by 2030 because automation will threaten 51% of all jobs. Consequently, Singapore wants to adopt Industry 4.0 to weather these shifting global trends requiring the acquisition of critical, in growing demand, and transferable skills, including that of 3D modelling. As a result, there is a need to create effective methods for instructing adult learners in 3D modelling. To address the difficulties experienced by adult learners, this study provides a format for teaching basic and intermediate 3D modeling abilities within the context of 3D computer animation.

Theoretical Framework

The fourth industrial revolution, known as Industry 4.0, is defined by the integration of cutting-edge technology like artificial intelligence, robotics, and the Internet of Things into industrial processes. This study explores the significance of 3D modeling abilities in this context, as it is seen as a critical skill that, due to its growing demand and transferability across sectors, can help workers adapt to the changing demands of the workforce and remain relevant in their fields (SkillsFuture, 2022).

3D modeling is the process of employing specialist software to produce a three-dimensional representation of a real-world item (Chong, 2019). In order to properly teach 3D modeling, it's critical to comprehend a number of related theoretical ideas. Polygonal modeling is a key component of 3D modelling. This entails building a collection of linked polygons to produce a surface that symbolizes the item being represented in 3D (Villar, 2020). Polygonal modeling is the act of manipulating vertices, edges, and faces to produce a model that precisely captures the form and dimensions of the item being represented (Chong, 2019). According to Siemens (2009) another 3D modeling technique used to produce intricate geometrical patterns and forms is procedural modeling.

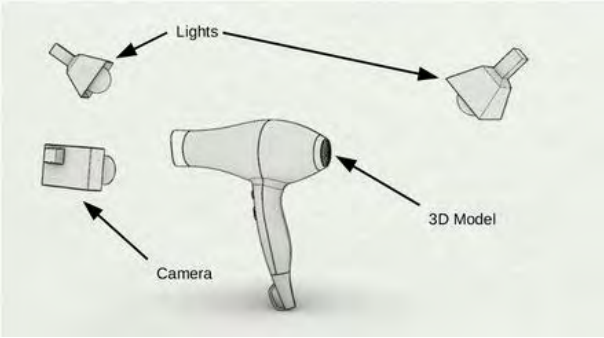

Figure 1: Elements for 3D models*. Note. Chong, S. P. (2019). Blender 3D Modelling: A Concise Guide to Version 3.0. Amazon KDP.*

This entails the use of algorithms to produce 3D models in accordance with a set of guidelines or specifications. The production of natural surroundings, including trees, rocks, and landscapes, frequently uses procedural modeling. Additionally, the employment of several software tools and methods, such as texture mapping, shading, and lighting, is common in 3D modeling. In order to give detail and realism to a 3D model, texture mapping involves applying a two-dimensional picture, or texture. To give the appearance of depth and volume in a 3D model, shading implicates applying colour and shading. Lighting entails replicating the effects of light sources on a 3D model to produce a lifelike depiction of the thing being represented. Generally, for teaching 3D modeling effectively, it is crucial to comprehend these theoretical ideas (Villar, 2020). Learners can acquire the abilities required to produce precise and realistic 3D models that can be used in a variety of sectors and applications by giving them a firm understanding of these principles.

The pool of students came from different backgrounds such as those who work in digital media, beginners who are new to the animation field, and professionals from other industries. These comprised different age groups, from young workers to seniors, and included citizens, permanent residents, foreigners, and employees sponsored by their company. The participants also had different levels of computer skills, ranging from experts to those having limited exposure. Due to this diversity, the needs, and dynamics they brought to the class were multifaceted. Therefore, the format and andragogy utilized in the courses were carefully chosen to ensure that they amplify the adult learners' potential. As indicated by Greenberg (2009), in a physical setting, stimuli including perception, intake, time, and mobility have an impact on adult learners. The processing of information by students involves a variety of senses, including the auditory, visual, and tactile. Each learner's preferred sense can be determined by the instructor, who can then best support that learning style. As a result, physical classes were chosen over other online learning formats. Additionally, small-size classes were arranged as research shows that, due to changes in the learning environment, increase in class size has a detrimental influence on learner's performance, particularly for learners from disadvantaged backgrounds. Instructors respond to increasing class numbers by expecting students to take more responsibility for their own learning, which results in reduced pupil-teacher engagement (Fredriksson et al., 2014). The length of each course was decided to be 7 hours only to make them less daunting to the learners, but still providing enough time for learners' acquisition of knowledge and skills. Each course was delivered over two consecutive evenings, from 7 to 10:30 pm at the Nanyang Polytechnic campus computer laboratory, which provided all equipment and software needed for learning. Additionally, this time frame proved to be popular among working adults who would not have been able to attend daytime classes. For andragogy, microlearning (Boring & Tomei, 2022) was incorporated to provide short, focused bursts of of bite-size learning that can be quickly consumed by adult learners. Each 3.5-hour lesson was broken down into smaller segments with short breaks in between for the learners to review the material and ask questions. Project-based learning (Pusztai, 2021) was used to help adult learners apply their understanding in real-world scenarios. Multiple small projects were given throughout the delivery of the lessons, to provide tangible milestones to practice the newly acquired knowledge. Learners were assigned a series of projects that were progressively challenging them to develop their 3d modeling and animation skills. Lastly, storytelling (Bonds, 2016) was implemented to make their learning experience more engaging and memorable. Each practical activity included a narrative to offer context and scope while also ensuring that learners had fun during the process.

Table 1: Course format key aspects

In-person setting	• engaging all senses • individualized support of preferred learning style
Small size class	• increased pupil-teacher engagement time • personalized feedback
Short duration	• less daunting • enough time for acquisition of knowledge and skills
Microlearning	• bite-sized information • quicker to consume by adult learners
Project-based	• application of skills in real world scenario • tangible milestones
Storytelling	• engaging and memorable experience

Methodology

The SkillsFuture platform was chosen as a method of reaching a wider audience. The platform is part of a national drive to help Singapore's residents reach their full potential, regardless of their socioeconomic status.
SkillsFuture is a comprehensive high-quality system of education and training that can adapt to society's ever-changing needs (“About SkillsFuture”, n.d.). The portal is accessible to all residents of Singapore, however there are certain advantages exclusively available to citizens and permanent residents, such as subsidized course fees and the latter also receive credits to offset the fees. Additionally, upon successful completion of each course, the participants will receive a Certificate of Completion (COC) signed by the directors of Centre of Industry & Lifelong Learning and School of Design & Media of the Nanyang Polytechnic, which adds recognition to their learning.

Blender, a popular open-source program for producing 3D models and animations, was selected as a tool for teaching 3D modeling in the SkillsFuture courses. Its features and functionalities were taught in the courses to assist students understand the common tools and techniques utilized in 3D modeling. Furthermore, Blender's accessibility makes it an excellent choice for adult learners. The GNU General Public License (GPL) allows for free usage of Blender for any purpose, and its simple installation process makes it a viable choice for students who may not have access to expensive software or have minimal technical knowledge.

Three 7 hours long courses were created, where the first course, "Blender for Beginners," served as a broad introduction to Blender and covered procedural modeling, texturing, lighting, and rendering techniques in addition to key 3D modeling methods. The goal of the course was to provide students a strong foundation in the program and equip them to make simple 3D models. A sample of how the first course was structured to fit within the 7 hours timeframe is presented in Table 2. The second course, "Digital Sculpting with Blender," went into further detail into a specific modeling method known as sculpting. This approach enables the user to freely form shapes simulating traditional clay sculpting. The course was created to assist students in mastering the sculpting approach and using it to generate complicated 3D models. "Grease Pencil in Blender," the third and final course, focuses on creative concept generation approaches that may be utilized to swiftly produce ideas for 3D models. It also teach students how to showcase models in a cartoon form, which is becoming increasingly popular in the creative industry. The course was created to assist students in developing their 3D computer animation skills and applying it to the creation of attractive 3D models. An essential component of the classes was providing learners with thorough lesson notes at the conclusion of each course. These notes were a useful tool for students to review and solidify their comprehension of the course material. Along with instructions and screenshots to lead students through the creation of 3D models, the lesson notes included a summary of the major ideas and methods covered in the course. Links to additional resources and tutorials were also included in the lesson notes to help learners continue to learn and advance.

The evaluation techniques used in the Blender courses were created to measure course effectiveness by assessing participants' practical skills and understanding of the course content. The courses were practice-oriented, with various small-sized exercises delivered in each 3.5-hour class over two days. These tasks were created to assess learners' understanding and skill gain in 3D Modelling and Computer Animation. At the end of each course, the instructor gathered the completed tasks to check the learners' comprehension and application of the course contents.

Table 2: Blender for Beginners class, first course schedule breakdown

Day 1

19:00-20:45hrs	• Introduction • User Interface • Navigation • Object Level interaction • Modelling
20:45-21:00hrs	Break Time
21:00-22:30hrs	• UVs • Texturing • Shading

Day 2

19:00-20:45hrs	• Lighting • Eevee Rendering • Cycles Rendering (part1)
20:45-21:00hrs	Break Time
21:00-22:30hrs	• Cycles Rendering (part2) • Compositing • Grease Pencil

Results and Discussion

At the end of each course the learners were given a feedback form to complete which contained a set of questions/statements to be rated from 5 or strongly agree (excellent), to 1 as in strongly disagree (very poor).
A sample of questions asked is the following:

1. The general environment (e.g. training room, equipment, seating) was conducive to learning.
2. The concepts and skills taught are useful for my work.
3. The duration of the course is appropriate.
4. The course has met its stated objectives.
5. My overall rating of the course.

The courses’ overall average response to all questions is 4.5. The training space, furnishings, and equipment were deemed appropriate and conducive to learning by the students. These are essential elements of the in-person setting, as they helped the learners to remain engaged and focused throughout the course delivery. In addition, the attendees were also pleased with the staff, who were described as pleasant, prepared and helpful in guiding them in the physical class setting. This is another relevant factor in the in-person component of the course format as it contributed to the participants' favourable learning experience.The learners had a positive overall experience with the courses, having the majority of them saying that it met its purposes. Furthermore, several of them gave the course high marks, suggesting that they were pleased with the instruction they received. This is solid indication that the course format was effective in providing learners with the skills and knowledge they needed to improve their expertise in 3D modeling and computer animation with Blender. In addition, the feedback form included a combination of yes/no and open-ended questions to gather additional information. The questions are as follows:

1. Will you recommend your colleagues/friends to attend this course?
2. Other comments about this course?
3. What other course/training areas would you be interested in?

90% of the learners reported they would recommend the course to colleagues and friends displaying a high satisfaction level. The open-ended comments given were overwhelmingly positive, as per samples below:

1. The 2-days course was definitely a big help in starting my journey to learning more of the Blender programs. It provided sufficient info to transit my current knowledge of other 3D software into this one. If there was an advance course, I will consider taking it.
2. Easy, clear and concise. Materials supplemented were efficient and hands on, making it easy to grasp.
3. Glad that NYP conduct these courses and have learned good pointers from the trainer. Looking forward to the next blender course.

The remarks highlight strengths in the chosen format, like ease of understanding achieved via project-based and storytelling andragogy.

Nonetheless, an area of improvement mentioned by participants was the courses' duration which was deemed insufficient by some and that few more hours should have been allocated to deliver them. This feedback suggests that some adult learners might need more time to comprehend complicated information and put new skills into practice. In order to ensure that the material is sufficiently covered, and the students have enough time to practice and reinforce their new knowledge, it may be advantageous to consider adjusting the course duration for subsequent courses. Additionally, offering extra resources like online tutorials and reference materials could be beneficial in assisting students' ongoing practice and development outside of the classroom.

Conclusions

The majority of adult learners gave the courses positive ratings, with a 90% high rate for several questions on the evaluation form, according to an analysis of the data collected. This indicates that the chosen format of teaching 3D modeling skills to adult learners through the courses was deemed successful. The use of Blender as a tool for imparting knowledge of 3D modeling was another strength. Blender is a great option for adult learners who might not have access to expensive software or have little technical expertise because of its accessibility and affordability. The structured teaching of specific Blender features and functions in the courses helped students comprehend the tools and methods needed to produce 3D models. One of the weaknesses of this study was the limited sample size of adult learners who took the courses where a bigger sample size would have resulted in more precise findings and improved the data's generalizability. Additionally, the evaluation forms only provided limited feedback and did not include in-depth interviews or observations of the learners in action. In conclusion, the format discussed in this paper has proven to be successful at teaching adult learners the fundamentals of 3D modeling. It has been found that in person and small size classes are effective methods for increase students' engagement and personalized learning. In addition, the use of microlearning, project-based learning and storytelling was found to be an effective andragogy enabling the learners to acquire the desired knowledge. Overall, the course format has been proven to be promising, with some reservation on the length of each run which might need to be extended in future iterations. Future studies can investigate how well these courses work in various situations and with various populations, as well as how well they work when different andragogies and teaching techniques are used. The three introductory courses for adult learners' success in teaching 3D modeling skills illustrates the potential for further growth in this field. Based on the study's positive findings, it is suggested that additional courses be created for learners who have already finished the basic courses. These courses may provide learners with further specialized knowledge and skills expanding their understanding of 3D modeling.

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The Impact of Metaverse and Virtual Idols Technologies to Teaching and Learning

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Abstract

Virtual idols are not a new concept. The first generation of these artificial celebrities were developed for the ACG industry of Japan (animation, comic and games) in the 1980s. In recent years, the rapid advancements in social media platforms, Metaverse, cloud computing, big data and A.I. technologies, helps the development of photo-realistic digital characters to be applied in different areas to express themselves in more intimate, immediate ways and garner massive fan bases.

In China, the rise of Bilibili in 2020, a video platform that is favoured by ACG fans, stimulated the vast development and application of virtual idols on the platform. Based on the statistics provided by Bilibili released in 2020, there were around 32,400 virtual idols hosted livestreams on Bilibili in 2020. The people behind them are known as "Vtubers".

Our project team has been investigating in the relevant field starting in 2020, and developed the Phase I virtual idol MetaHuman, supporting three distinguished characters, namely, IT Sarah, IT Hana and IT Sophia with Unreal Engine. IT Sarah and Hana are dubbed behind the scenes and captured in real-time, while IT Sophia is an AI chatbot.

With the enhanced experiments provided to the students through virtual classroom, workshop collaboration and project cooperation through the virtual idols, positive results have been found. The virtual idol project team therefore starts the Phase II focusing on the adaptation of AI technology which empower the virtual idols with higher degree of interactivity, content filtering and the latest advancements in natural language programming (NLP).

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Keywords: *metaverse, virtual idols, AR, VR, MR, XR NLP, artificial intelligence (AI), chatbot, google cloud service, Unreal Engine, OpenAI, Azure cloud service*

1. Introduction

1.1 The Evolution of Virtual Idols

The evolution of virtual idols has been a fascinating phenomenon. Virtual idols are computer-generated characters that are designed to appear as singers, dancers, and other performers. They are typically used in marketing campaigns and have become increasingly popular over the past decade. Virtual idols are created using a combination of 3D modeling, motion capture, and voice synthesis technology. As technology advances, the capabilities of virtual idols have become increasingly sophisticated, allowing them to be more interactive and engaging with their fans.

Vtubers often project visuals which are designed to be aesthetically appealing. The majority of virtual idols fans are the demographic cohort succeeding Millennials and preceding Generation Alpha (Generation Z). Over 70% of these followers are aged between 18 and 23 (iiMedia research, 2021). More international brands and organisations like Louis Vuitton, Tesla, KFC and Givenchy have commissioned virtual idols for promotional campaigns world-wide. It is for sure that in the future, metaverse environments will also offer new places for virtual idols to interact with followers and fans. They will be involved in various digital entertainment sectors and industries.

1.2 AI Voice Overs with Emotions

AI voice overs with emotion refer to the use of artificial intelligence (AI) technology to generate spoken content such as speeches, narrations, and audio recordings that exhibit a range of emotions. This technology uses machine learning algorithms and natural language processing (NLP) techniques to analyse and interpret text input, then generate human-like voices that convey various emotions such as happiness, sadness, anger, and excitement. The goal of AI voice overs with emotion is to create more engaging and personalised audio content that can connect with audiences on a deeper level. This technology has a wide range of applications in industries such as advertising, entertainment, and education.

Natural Language Processing (NLP) is a sub-discipline of artificial intelligence and linguistics. This field of NLP has been discussed in the previous paper released by the team in 2021, so that it will not be covered again in this paper, instead the AI generated voice over will be researched and how virtual idols can be benefited from it.

Murf.AI Studio

Murf.AI Studio is an AI enabled, real people's voices platform that created studio-quality voice over in minutes. It converts from text to speech with a versatile AI voice generator, to be used by virtual idols.

Microsoft VALL-E

A Microsoft new text-to-speech AI model that can closely simulate a person's voice when given a three second audio sample. Once it learns a specific voice, VALL-E can synthesise audio of that person saying anything. The API also provides probability to simulate emotion.

So we started to research and use the

So we started to research and use the API to do it in a way that attempts to preserve the speaker's emotional tone to be applied in the virtual idols for course promotional and teaching purposes.

1.3 AI Powered Virtual Idols

The project team has been researching the Microsoft Azure OpenAI technology in the Virtual Idol project Phase III development. The project team's vision speculates that VALL-E could be used for high quality text-to-speech application, speech edition where a recording of a person could be edited and changed from a text transcript and audio content creation when combined with other generative AI models like GPT-3.

Based on the technology, the new virtual idols could generate discrete audio codec codes from text and acoustic prompts. It basically analyses how a person sounds, breaks that information into discrete components and uses training data to match how that voice would sound if it spoke other phrases outside of the three-second sample.

Figure 1 Virtual Idol - Ava & Max

2. Promotion & Education

2.1 AI Powered IT Hana & IT Sophia

Similar to IT Sarah, the difference is that IT Sophia and IT Hana are in a Metaverse. Students use MOTION CAPTURE to transform into IT Hana, interact with artificial intelligence IT Sophia, and promote our activities and information.

2.2 Observe learning progress

All Screens is designed to allow teachers to "close seven at a glance" and view all of their students' computer screens. Our team builds a cloud platform through Amazon Web Services (AWS) server architecture and uses AR and 3D animation to design "virtual assistant teacher Ma". Through a system where teachers ask students to share screens at all times, learn about students' computer activity, and through their pre-existing webcam setups, AI technology is used to detect the range of head movements to determine if students are distracted or suspected of cheating.

2.3 Education

When students turn on their webcams, artificial intelligence technology is used in the background to recognize students' faces and detect their eyes, head movements and computer screens. Once suspicious, it will issue a warning or notify the teacher, increasing the difficulty of cheating in disguised form and acting as a deterrent.

3. Methodology

3.1 IT Hana & IT Sophia

The team used Unreal Game Engine from Epic Inc. and MetaHuman to create unique realistic human models for the Virtual Idos in Phase I. The motion capture system vividly recreates the real-time facial expressions which enables IT Hana to show movements and expressions in virtual environments. In Phase I, the motions of the virtual idols are pre-recorded and captured with a motion capture system. The limitation with the previous method is that the virtual idol will have limited variations in the motions and facial expression based on the limited number of captured motions.

Figure 2 motion capture movement of Metahuman IT Hana

To improve the motion contents to IT Hana and IT Sophia, Procedural Animation will be tested and further implemented as the Live Animation System. Generally speaking, a procedural animation is a type of computer animation, used to automatically generate animation in real-time to allow for actions, which then could otherwise be created using pre-defined animations. Procedural animation is used to simulate particle systems, such as rain, fire and fog, cloth and clothing, rigid body dynamics, hair and fur dynamics, as well as character animation. In video games, it is often used for simple or complex actions such as turning a character's head whenever a player looks around. These techniques are programmed to have Newtonian physics acting upon them, therefore they are very realistic effects that can be generated that would be pretty hard to recreate with traditional animation. More complex examples of procedural animation are user-created creatures or 3D models, which will automatically be animated to all actions needed in the game from walking, to driving, to picking things up.

In the latest development phase, our team will design and implement simple procedural animation of body movement to the virtual idols, when the virtual idols are talking, greeting, laughing, etc. So these can improve the combination of body language of the virtual idols, as well as the realistic real-time response and interactions between the virtual idols and the users.

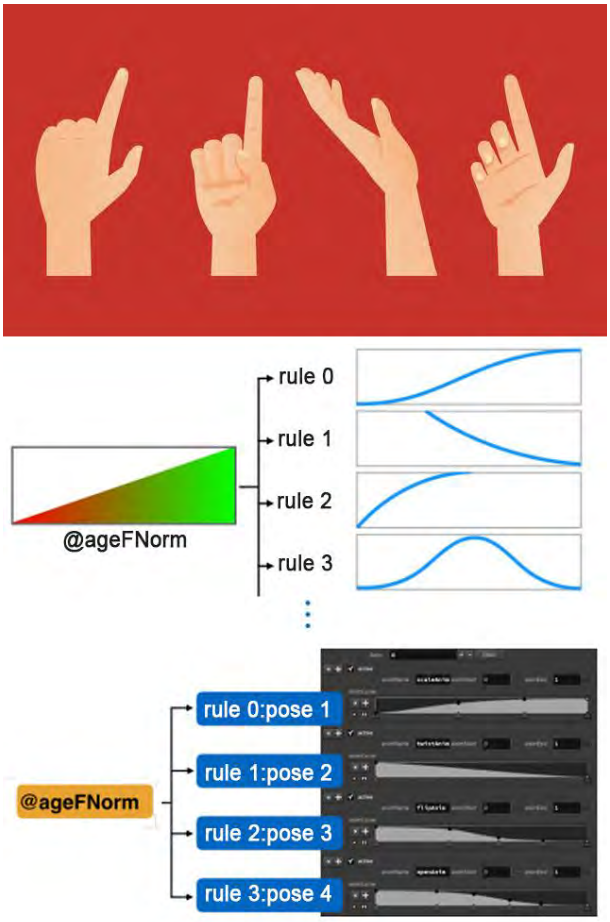

Figure 3 Norm sample of AI procedural animation learning of the AI model

3.2 Synthesise Personalized Speech

Synthesis is the voice content of Artificial Intelligence(AI) technology individuals' unique needs, preferences and characteristics. The technology uses algorithmic algorithms and natural language processing (NLP) technology to identify their age, gender, location, and even their tone of voice. Based on this analysis, a human-intelligence system can generate a personalised language that is more powerful and relevant to the individual.

Synthesised and Personalised voice and speech have been used in many commercial and industrial areas. For example, healthcare industry, digital entertainment industry and many more. It is used to create audio content that is tailored to customers' specific health conditions and provides tailored treatment plans. In education, personalised learning programs are designed and created for student to improve the student's proficiency level and learning style.

Collectively, the incorporation into a personalised language has the potential to revolutionise the way we create and consume audio content, providing individuals with greater appeal, interactivity, and relevance.

The project team will use Microsoft VALL-E to help improve the speech quality produced from text-to-speech results of the virtual idol. So that it is expected to add "emotion" to the synthesised speech with ultra realistic AI generated human voices. The goal of implementing VALL-E to the virtual idol is aimed to create a more immersive and interactive language learning experience. By combining audio, visual, and language data, the next phase of virtual idol can be more engaging and effective.

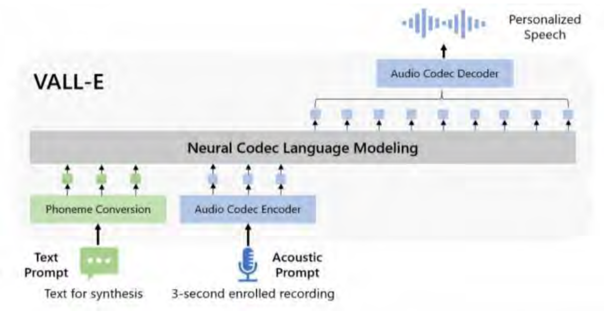

Figure 4 Model Overview of Microsoft VALL-E

3.3 AI Powered IT Hana & IT Sophia

The next generation IT Hana and IT Sophia will be an AI-powered virtual idol with a more realistic appearance, personality, and backstory. AI models will be developed for IT Hana and IT Sophia that can generate speech, facial expressions, and body movements for them. Further study on machine learning algorithms to analyse and interpret data, such as visual cues will be carried out within the project team. To collect data for training the new AI model. Audio recordings, videos, and images of mankind performers, as well as literature and text data will be collected to be used for generating speech and dialogue. Finally, the trained AI model will be integrated into the virtual environment, allowing the virtual idols to respond to user input in real-time.

Figure 5 AI Powered Smiling Facial Expression Testing of Metahuman IT Sophia

4. Result

The AI-powered Virtual Idols, namely, IT Hana and IT Sophia, have been enhanced in terms of appearance, facial expression, efficiency and body movement. They have been used in the departmental information day to help promote the courses provided by the institute to the public, fun-interaction with the guests, virtual tour-guide to the visitors, and animated greetings to welcome the honourable VIPs.

Besides, the researched AI algorithms and latest technology have been included in the course teaching materials for the I.T. in an attempt to equip the students with the most up-to-date professional knowledge and skills of AI and virtual idol. Synthesised voice technology has been applied in other digital game and VR App development projects.

5. Conclusion

Creating an AI-powered virtual idol is a complex process that requires a team of experts in AI, graphic and animation design, and programmers. However, with the right resources and expertise, it is possible to create a virtual idol that can engage with users in new and exciting ways. In the coming future, there will be more interactive ways between the teachers, students as well as the audience's virtual idols are also worth looking forward to.

Our team will continue to bring more learning opportunities to students by optimising the virtual idols, including tailoring various costumes to make the appearance of virtual idols more varied; and allowing more interaction between virtual idol and human users, and communication between AI-powered virtual idols to explore if more impacts can be created through these developments.. In addition, the information technology discipline will also encourage students to create other virtual idols to broaden their application and enrich their learning experience.

Acknowledgements

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THE ROLE OF STUDENT SDGS PROMOTER AND ITS IMPACT ON BOTH INSIDE AND OUTSIDE OF THE UNIVERSITY

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Abstract

Nagaoka University of Technology (NUT) has been promoting SDGs activities and NUT was appointed as the global hub university of the United Nations Academic Impact (UNAI) for SDG9 (Industry, Innovation and Infrastructure) for two consecutive terms, as a model university for innovative efforts related to the SDGs (Sustainable Development Goals). In 2019, the Office for the Promotion of Sustainable Development Goals (SDGs) was established to promote the university's activities toward the achievement of the SDGs in a comprehensive and effective manner through close cooperation with internal and external organizations. The following year, a student organization was established to encourage students to think freely about public relations activities and events to promote the SDGs and as well as initiatives to further build momentum for SDG promotion on campus, together with our faculty and staff members.

The student organization member "Student SDGs Promoter" was appointed by the president. As a member of the first SDGs promoters, a total of 13 diverse students were appointed, consisting of four Japanese students and nine international students of a wide range of ages, from undergraduate students to students with full-time jobs. In September 2020, the appointment ceremony for Student SDGs Promoter was held in a hybrid format considering the students who could not come to Japan due to the COVID-19 disaster. Currently, 28 students are enrolled as SDGs Promoters and involved in various SDG activities. In order to deepen children's understanding of the SDGs while having fun, SDG education materials and games developed by our university are introduced free of charge on our website. Through these contents, the SDGs promoter organizes events, and event participants are given the opportunity to explain about a sustainable society and learn about the SDGs. As the UNAI hub university of SDG9, we will introduce how the university works with local governments to achieve SDG4 and realize a world where no one is left behind.

Keywords: *SDGs, Student SDGs Promoter, SDGs educational materials and games*

Introduction

Nagaoka University of Technology (hereinafter designated as NUT) was originally established in 1976 with a clearly defined mission. NUT aimed to nurture and developed leading, practical engineers who have the potential to instigate innovation and drive technological advancements. Upholding the university's motto, the Spirit of Vitality, Originality, and Services (VOS), NUT continues to provide high-quality education in engineering.

Most of the students at NUT have a rich academic background, often originating from KOSEN (College of Technology). 80% of NUT students choose to continue their studies at NUT as third-year students, participating in uniquely structured programs that provide an integrated Undergraduate–master's engineering education. These programs equip students with the comprehensive knowledge and skills required to excel in the engineering field.

NUT is particularly renowned for conducting an engineering education based on the concept of "GIGAKU," also known as the Science of Technology. The objective of GIGAKU is to foster innovative human resources that can transform and revitalize the industry sector. The education model is designed not only to impart core academic knowledge but also to develop practical skills in the field.

Through its unique engineering education, NUT successfully fosters individuals who are not only experts in their respective fields but are also capable researchers, innovators, and practitioners. Furthermore, these individuals grow into individuals of high integrity and develop the capability to apply their technical knowledge through collaborations between academia and industry.

In 2017, NUT took a pivotal step forward by incorporating the concept of Sustainable Development Goals (SDGs) into its existing educational programs. This led to the establishment of the "GIGAKU SDG Institute," The new program represents a significant evolution of the original engineering education, explicitly aiming to contribute to shared global goals and foster a better society. The GIGAKU SDG Institute, to which we have applied, is recognized by the UNESCO Chair Program. It promotes the establishment of a practical engineering education system with a focus on creativity and a commitment to contributing to the achievement of the SDGs. This is achieved through industry-academia collaboration and international cooperation. In conjunction with our partner universities, who share these fundamental educational principles, we have applied to the UNITWIN program and have been granted permission to establish a UNITWIN Network (GIGAKU SDG Network) in 2023.

Numerous student activities occur, such as the student-led international conference "STI-Gigaku," and the development of educational materials related to the SDGs by students of the Science of Technology Innovation, the 5-year Integrated Doctoral Program. These commendable efforts led to the United Nations Academic Impact (UNAI) appointing the NUT as the SDG9 Hub University for the first term, which lasted from 2018 through the end of May 2021.

Following this successful term, NUT has been reappointed as the SDG9 Hub University for the second term, which runs from 2021 through the end of May 2024. In this crucial role, NUT continues to promote education and research aimed at achieving all objectives related to Goal 9 of the SDGs, which is centred on Industry, Innovation, and Infrastructure. Additionally, the university is working to promote social contribution activities aimed at achieving the SDGs. As the world's only SDG9 hub university, NUT is committed to making a significant contribution to global development and innovation.

Student Organization "SDGs Promoter"

NUT has established the Student SDGs Promoter, a student organization tasked with promoting the understanding and awareness of the SDGs both on and off campus. This initiative encourages students, faculty, and staff to collaboratively think about and pursue activities aimed at achieving the SDGs. Candidates for the Promoter role, regardless of age or nationality, should be (1) NUT students who have a strong interest in the SDGs, (2) willing to contribute to NUT's SDG promotion activities alongside faculty and staff, and (3) capable of publicizing the SDGs, planning events, and prioritizing teaching and research. Selected candidates are then interviewed and appointed.

In the first appointment, a diverse group of 13 students—9 international students and 4 Japanese students, ranging from undergraduates to working adults—were appointed as Student SDGs Promoters. An appointment ceremony was held both in-person and online to accommodate students unable to travel to Japan due to the ongoing effects of the novel coronavirus.

During the appointment ceremony, each student receives a letter of commission from the NUT president and an orange T-shirt, symbolizing SDG 9, in recognition of the United Nations' designation of the university as a hub university. At present, there are 18 active Student SDGs Promoters. Additionally, there are now 31 alumni who support the organization by publicizing events related to the SDGs.

SDGs Promoter-organized events

Although NUT has been appointed as a UNAI SDGs Hub University and society expects corporations to contribute to the SDGs, not all faculty and staff members and students have been adequately engaged with the SDGs. A survey (non-disclosure) conducted on campus regarding interest in the SDGs revealed that a few, but not many numbers of faculty members and students are either unaware of the SDGs or have no interest in them. Therefore, in an attempt to increase awareness and understanding of the SDGs among the campus community, we organized an event led by the Student SDGs Promoter, which included a seminar conducted primarily online.

CPR (Cardiopulmonary Resuscitation) seminar:
This seminar was organized by the student based on ideas that emerged from SDGs Promoters discussions. It was held on September 29, coinciding with "World Heart Day," to spread knowledge about CPR, which can save lives in emergencies, and raise awareness of SDG3, "Good Health and Well-being." The SDGs Promoter, a graduate from a medical school in Mexico, led the session (Fig.1). Following his presentation, which

Fig. 1 Students taking the CPR Seminar

used slides and videos, participants practiced CPR using a resuscitation mannequin and training AED (Automated External Defibrillator), guided by an English audio version.

Webinar on Elimination of Violence Against Women:
The seminar was scheduled to coincide with the "International Day for the Elimination of Violence against Women" on November 25, the final day of the "Campaign for Eliminating Violence against Women" running from November 12-25. The purpose of this seminar was to raise awareness about the various forms of violence and discrimination that women around the world, including in Japan, face.

The seminar was conducted online and simultaneously streamed via social media to enable participation from anyone interested, including those at overseas universities. A Student SDGs Promoter gave a presentation on numerous cases from around the world, including Japan, using materials prepared in both English and Japanese (Fig.2). The guest speaker, Mr. Ayesh Madushanka Wijayasinghe from the Sri Lanka Press Council, gave a presentation on "The Impact of Media on Violence against Women."

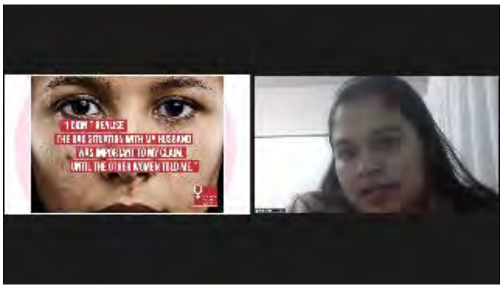

Fig. 2 Lecutered by the international student from Sri Lanka

Seminar “Let's Talk Diversity! Seminar on LGBT+ and GSRM” :
This seminar was held during "Trans Awareness Week" (November 13-20) to share the difficulties faced by LGBT+ and GSRM individuals and to inspire attendees to think about potential solutions for the future (Fig. 3).

Fig. 3 Lecutered by the international student from Mexico

The seminar was conducted online, allowing participation from foreign universities. A Student SDGs Promoter clearly explained the basics of LGBT+ and GSRM, their relevance to the SDGs, and the challenges faced by social minorities in Japan and abroad. Presentation materials were prepared in both English and Japanese.

This seminar offered an opportunity to gain knowledge on various topics, such as information on support groups and help desks, discussions on sexual diversity and sexual minorities, and initiatives for gender equality.

Webinar on Refugees and SDGs:
This seminar was held online and simultaneously streamed via social media. A student gave a presentation, using materials prepared in both Japanese and English, which primarily focused on the relationship between refugees and the SDGs.

The guest speaker, Ms. Parwana Amiri, is an activist from Afghanistan who has published books based on her personal experiences as a refugee (Fig. 4). She discussed her evacuation from her country, the current situation of refugees in other countries, and her experience of setting up a school (Wave of Hope for the Future) in a refugee camp alongside other refugees. Ms. Amiri has established an organization called "Youth Refugee Movement" to promote Sustainable Development Goals, particularly Goal 5 (Gender Equality), among refugee youth.

In Japan, refugee issues seldom come to the forefront of daily life. However, through this webinar, we have been able to emphasize that they are globally recognized as matters of significant importance.

Fig. 4 Ms. Parwana Amiri, an activist from Afghanistan

The activities carried out by the SDGs Promoters have sparked increased interest in SDGs-related matters within universities. For instance, they have emphasized the importance of having AED instructions available not only in Japanese but also in English. Additionally, they have facilitated an environment where students wishing to use a pseudonym based on their gender identity can do so at their request.

Contributing to the local community

NUT not only organizes SDGs-related events and seminars to promote the SDGs beyond its university activities but also actively participates in events sponsored by Nagaoka City. SDGs Promoters explain the SDGs to attendees, including children and their parents at these events. This is part of NUT's effort to achieve the SDGs through collaboration with the local community and educational institutions.

Exhibited SDG booth at HAKKO trip:
SDGs Promoters participated in a family-friendly event titled "Nagaoka City, a Place of Fermentation HAKKO trip" held at Nagaoka City Hall Aore. As part of their promotional efforts, the students set up a booth to introduce the NUT's SDGs activities, aiming to raise awareness about the SDGs within local communities.

The event attracted a large number of visitors, including many children and their guardians who visited our SDGs booth. SDGs Promoters provided opportunities to understand sustainable societies through board games (like SDG Carom and SDG Activity games), creating an enjoyable and educational experience around the topic of SDGs (Fig. 5 and 6).

Fig. 5 SDGs Carom

Fig. 6 SDG Activity games

Beach Cleanup × Learning:
The event, titled "Beach Cleaning x Learning," was held at Nagaoka City's Gomoto Beach. With the core concept of learning about the sea and science while cleaning the beach, it saw participation from members of NUT, primarily student SDGs promoters, as well as local residents.

Participants picked up litter on the beach, separating the garbage by local rules. This included the collection of plastic bottles, plastic products, and microplastics — plastics that have deteriorated due to ultraviolet rays and radiation and have become less than 5 mm in size. Following the beach clean-up, participants engaged in learning activities about the sea and science, such as practicing the process of making iron from iron sand collected on the beach (Fig. 7 and 8).

Fig. 7 Beach cleanup

Fig. 8 Thermite process with Sand Iron to make iron

NUT conducted a questionnaire survey on the SDGs among about 400 residents (who used city hall at that time) of Nagaoka City. In fiscal 2020, approximately 23% of respondents reported that they either "did not know what the SDGs were" or were "not interested in the SDGs." However, the proportion of Nagaoka residents interested in the SDGs increased by about 10% in fiscal 2021.

Also, when asked whether they were aware of NUT's designation as a hub university, the percentage who knew about it rose from 25% in 2020 to 31% in 2021. While the rising interest in the SDGs among Nagaoka citizens can partly be attributed to the overall increasing interest and activities related to the SDGs in Japan, we believe that the university's efforts have also made a significant contribution.

Conclusions

The visibility of NUTs SDGs activities among the Nagaoka City resident suggests that SDGs promoters are effectively promoting social contribution activities. These are aimed at achieving the SDGs and include creating opportunities for people to familiarize themselves with the SDGs through events, raising awareness of the SDGs in the local community, and spreading the understanding that the SDGs are for everyone's problem.

Despite the halt in progress toward the targets due to global pandemics, natural disasters, and wars, we have now passed the halfway point to our target year. The increasing interest in sustainability and the growing collaboration between industry and academia under the SDGs goals are becoming more prominent.

Certainly, NUT students, including the SDGs promoters, are future candidates for roles as SDGs-minded practical engineers, and their potential is highly valued by the industry. We hope that the SDGs Promoters will continue to intensify their efforts, introducing innovative ideas to achieve the SDGs, to contribute to a sustainable and improved world by 2030.

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Enhancing Physics Education Using Distribution of Video Lessons from Teams and Interactive Electronic Books

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Abstract

We have developed tools to enhance the deep learning of physics, using video lessons to support preparations and review for class and interactive electronic books (ebooks) to visualize theoretical understanding, for third year students in national colleges of maritime technology.

Students can use the gallery function of ebooks to understand physical quantities such as slopes and areas in differential and integral calculations, and to visually understand formulas derived from integrals of equations of motion.

Furthermore, using video lessons distributed in MS Teams group chat according to the progress of each class. The students can study the key points of the class and answers to the questions at their own pace at any time and in any place. Each video lesson is about 20-30 minutes, and there are more than 50 videos for first to third year students in total. Moreover, the students replied to the Teams video chat with a comment and the students reacted 👍 to each other's comments.

From the results of a student questionnaire given after the exercise, 73.7% of the students found the electronic books to be helpful and 92.1% of them understood the velocity and acceleration calculated by differential and integral calculus. Additionally, 84.2% of the students found the video lessons in the Teams to be useful and 75% of them found the replying to video chats with what they understood or noticed helped them learn. Moreover, it was found that the most common scene in which the video lessons were useful for students was studying for periodic exams.

In 2022, computer-based testing at the National Institute of Technology for class A, the correct answer rate of the questions on differential and integral calculus and displacement-velocity-acceleration was about 66%. This is an improvement over the 59-60% average at institutions not using this technology.

Keywords: *lesson video, MS Teams, differential and integral calculus and mechanics, electronic book, gallery function, theoretical understanding*

Introduction

Education for deep learning of physics is strongly demanded by society as it moves towards Society 5.0, as an education that nurtures creative knowledge that cannot be replaced by AI.

Since 2016, we have developed an interactive ebook (iBooks format) about differential and integral calculus and mechanics, and also checked the degree of understanding by linking to LMS(Blackboard) online examinations. In this ebook, the meaning of differential and integral is explained graphically and theoretically using the iBooks gallery function.

From 2021, by distributing video lessons using Microsoft Teams, we are trying to add the effects of independent learning and mutual learning. For students, class videos enable them to study at their own pace anytime, anywhere, including practicing problems in class, studying for exams, and studying at home when they are absent due to coronavirus or influenza infections.

The educational results of this approach are discussed on the basis of student questionnaires and results of CBT (computer based testing) at the National Institute of Technology (KOSEN).

Systematic understanding using ebooks

The ebook contains key summaries of differential and integral calculus and mechanics and contains questions and answers from the achievement examinations in KOSEN.

Using the gallery function of ebooks, we teach a graphical understanding of the mechanics of a particle. For example, in graphical understandings, the slope at any point on a distance-time graph gives the speed at that point in time, and the area under a speed-time graph gives the distance travelled as shown in Fig.1. Such a graphical method is very useful for deep understanding.

Moreover, using differential and integral calculus, in order to check their theoretical understanding, we provide theoretical graphs of physical quantities and formulas using the gallery function of ebooks. For example, in a theoretical understanding of the time integral over the equation of motion, we derive the formulas of velocity and displacement in linear motion of uniform acceleration as shown in Fig.2.

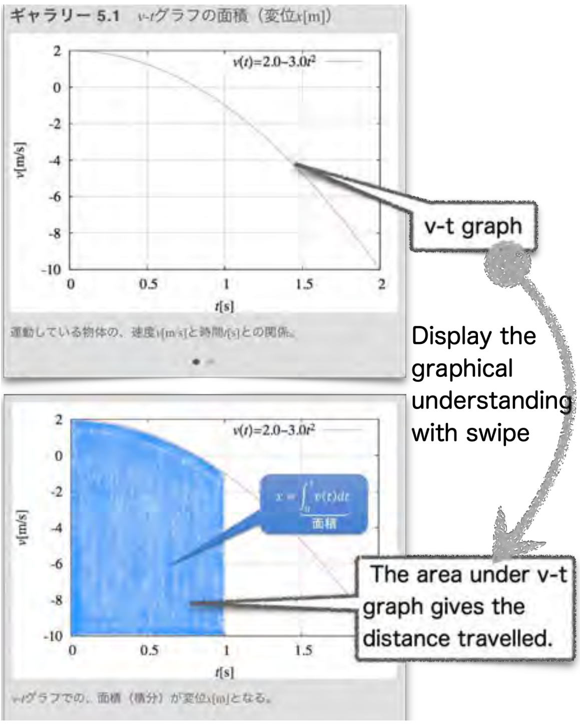

Figure 1. Gallery function of ebooks for graphical understanding.

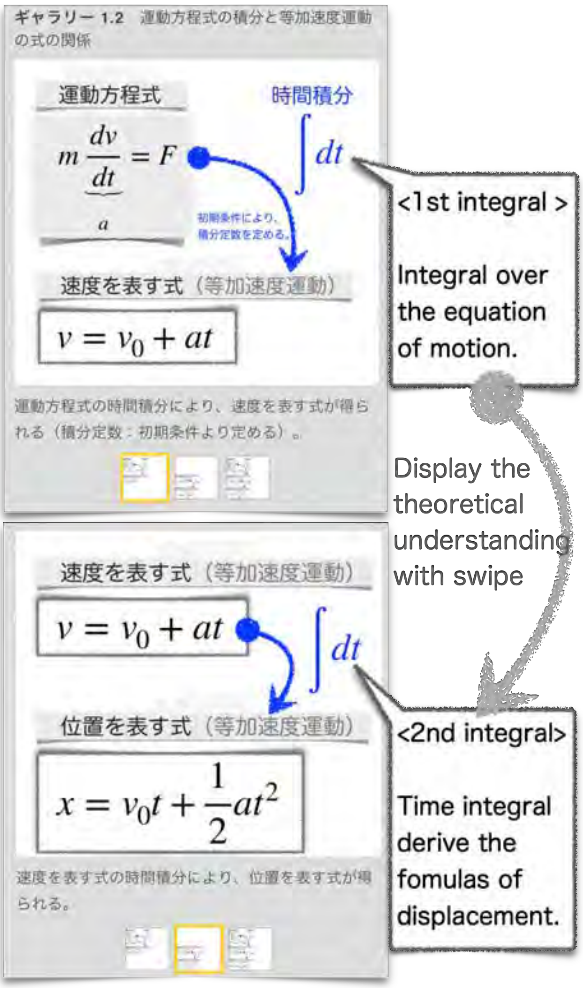

Figure 2. Gallery function of ebooks for theoretical understanding.

In order to understand the usefulness of differential and integral calculus for the calculation of physical quantities, ebooks also contain questions that required solving using either differential and integral calculus or with formulas. For example, we gave the following calculation questions in the exercise chapter.

On the x-axis, an object accelerates from 0[m/s] to 10t [m/s] in t [s].

(1) Calculate the acceleration of the object in the first 2.0[s].

(2) How far did the object travel in the first 2.0[s] ?

The ebook could be accessed via the homepage, http://www.hiroshima-cmt.ac.jp/faculty/ippan/007.html , and downloaded wirelessly to an iPad or iPhone.

Distribution of video lessons for preparation and review using Teams group chat

The video lessons are composed of a summary of the key points of the class and answers to the questions(Fig.3). Each video is 20-30 minutes long.

Using MS Teams group chat, we distributed a video lesson according to the progress of the class (Fig.4). For third year students, we have developed a total of 24 video lessons. They have watched about 50 videos since they were in first grade.

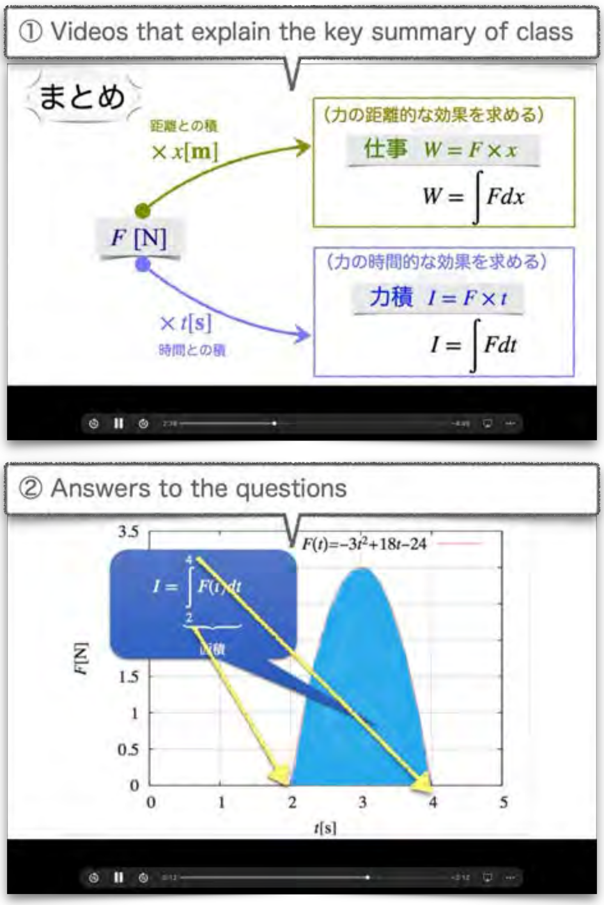

Figure 3. The video consists of two parts: ① Explanation of the key summary of class and ② answers to the calculation questions.

投稿 ⌄
[033]広島商船_4年_2022 > C4(2022)_掲示板

自分
1月19日、8:31

物理（予習・復習用）授業動画＜19＞

[redacted]

復習や試験勉強などで役立てて下さい。

＜授業動画19＞2階の微分と運動方程式「p.9(1)(2)の解答」
25.1 MB

👍28

D. 微分積分と運動方程式

•質量 m[kg] の物体の運動方程式

$$F = ma$$

$$m\underbrace{\frac{d^2x}{dt^2}}_{a} = F$$

[redacted]_広島学生 1月20日、10:48
質量m(kg)の物体の運動方程式を求める時は、2階の微分方程式を使って求めることができる。
👍3

[redacted]_広島学生 1月24日、1:01
小球の変異xは運動方程式の解としてAsinωt+Bcosωtと書けることがわかった。
👍3 2 1

[redacted]_広島学生 1月24日、1:17
初期条件がある時の計算方法がわかりました。😎
👍2 2 ❤1

[redacted]広島学生 1月24日、9:54
運動方程式の計算方法が分かりました
👍2

Figure 4. Mutual evaluation by commenting and reacting to the chat of Teams lesson videos

As a class exercise, the students solved the questions and watched the video lessons, and checked their answers.

Furthermore, the students replied to the video chat that they understood and wanted to be careful not to make a mistake. And, the students reacted 👍 to each other's comments (Fig.4). Reacting to the comments of others, the students deepened their understanding from various perspectives. The students also watched the video while paying attention to the comments that they found interesting.

Results and Discussion

Questionnaires were completed by third-year students of Class A in February 2022. A summary of their responses to the following questions is described below.

(1) Was the ebook for differential and integral calculus and mechanics useful as a study aid?
(2) I was able to understand the velocity, acceleration and displacement calculated by differential and integral calculus.
(3) Was the gallery function for graphical understanding useful as a study aid?
(4) I was able to understand the work and impulse calculated by differential and integral calculus.
(5) Were the questions on linear motion of uniform acceleration that can be solved using both differential and integral calculus and formulas useful as a study aid ?
(6) Were you able to systematically understand the various formulas derived from the integration of the equation of motions (such as the formula for uniform acceleration motion and the relational formula for momentum and impulse) ?
(7) The video lessons distributed using Teams were useful for understanding the learning contents.
(8) The video lessons were easy to watch due to the font size, illustrations, and ease of listening.
(9) Commenting on the Teams chat about what I understood or noticed after watching the video helped me understand the learning contents. (Replies are limited to students who have entered comments in the chat.)
(10) I learned and noticed by reading the comments of other students when adding reactions (like 👍, etc.). Replies are limited to students who have given reactions to other students' comments.
(11) How long was the video lesson? ① Very long ② A little long ③ Appropriate ④ A little short ⑤ Very short
(12) When was the class video useful? Please answer all that apply. ① Preparation ② Review ③ During class ④ Studying for exams ⑤ Others

According to the answers provided by the students, 73.7% of them found the ebook to be useful (Fig. 5(1)). Additionally, 92.1% of students understood the velocity and acceleration calculated by differential and integral calculus (Fig. 5(2)), and 78.9% of students could understand the work and impulse calculated by differential and integral calculus (Fig. 5(4)).

Additionally, 65.8% of students found the gallery function for graphical understanding useful as a study aid (Fig. 5(3)).

In Figure 5(5), 86.8% of students found the questions of linear motion of uniform acceleration that can be solved using both differential and integral calculus and formulas useful as a study aid.

And 76.3% of students understood the integral of equation of motions reduces various formulas (Fig. 5(6)).

In Figure 5(7), 84.2% of students found the video lessons useful as a study aid. Additionally, for 78.9% of the students, the visibility and audibility of the videos were good (Fig. 5(8)).

Among the students that comment on the Teams chat, 75% were writing comments on items that they had understood or noticed as study aids (Fig. 5(9)). Additionally, 57.9% of those students found reading other students' comments to be useful (Fig. 5(10)).

From Fig.6, we found that a video length of around 20 to 30 minutes was appropriate or slightly longer for the majority of students.

And, the students mainly used the videos when studying for exams, reviewing, and during classes as shown in Fig. 7.

Statements made by the students in the questionnaire concerning the ebook and videos are given below. The statements are paraphrases of the original Japanese statements.

● It was easy to watch the videos, which was useful for learning using the little free time available.
● The videos were helpful when I wanted to learn at a faster pace than the class.
● It was useful because I had to understand the contents of the video in order to think about comments.

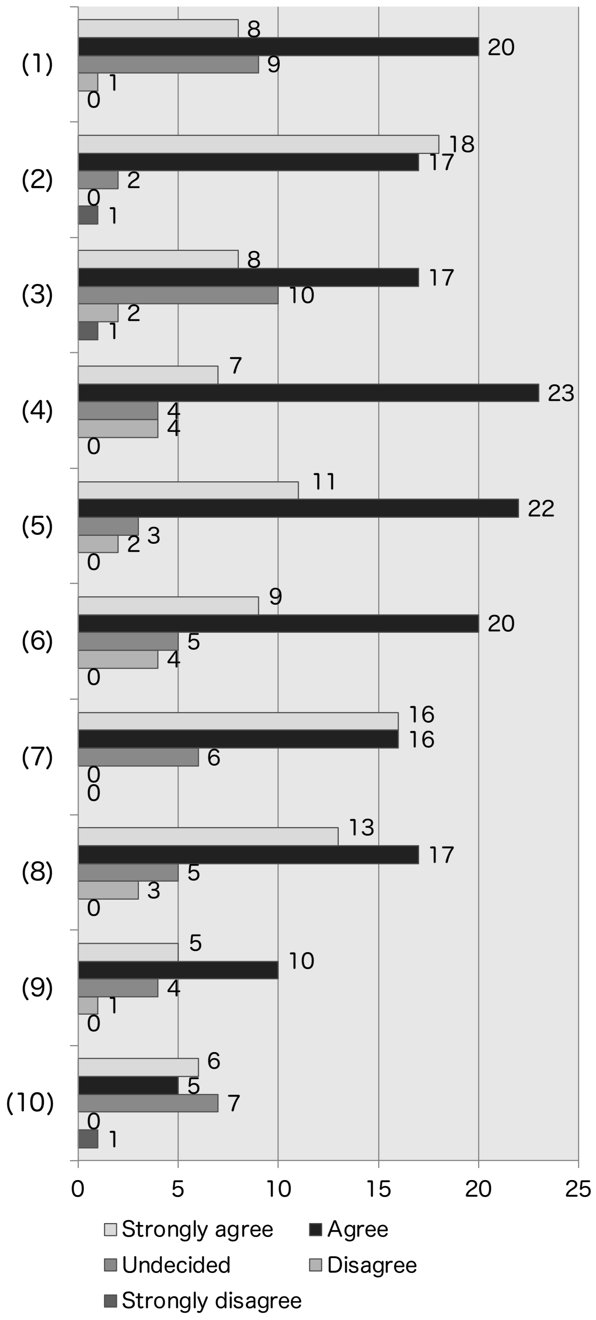

Figure 5. Results of a student questionnaire (1)-(10) of Class A in February 2023

- By writing the text of the chat comment, I was able to review it again.
- When I couldn't understand by watching the video, I was able to understand by reading other students' comments.
- The concept of differentiation and integration was easy to understand with the illustrations in the gallery function.
- The same answer was obtained using differential and integral calculus and 3 formulas. I was able to deeply understand the three formulas that I had simply memorized.
- When I missed class due to the flu, Teams videos helped me understand.

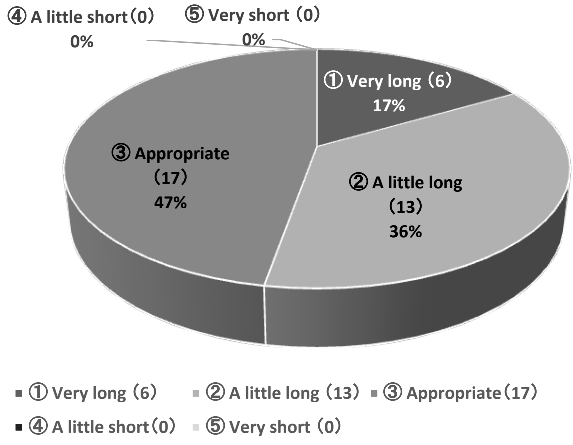

Figure 6. Results of a student questionnaire (11) of Class A in February 2023

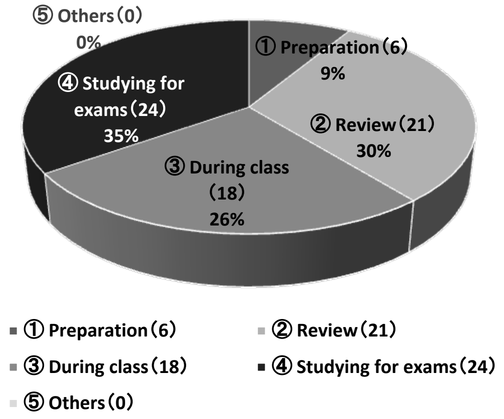

Figure 7. Results of a student questionnaire (12) of Class A in February 2023

Conclusions

According to the result of the questionnaire, 74% of students found the electronic books to be useful for study. And 84% of students found the video lessons useful as a study aid.

In the CBT examination of class A at our school, the National Institute of Technology in 2022, the correct answer rate of the question of differential and integral calculus and displacement-velocity-acceleration was about 66%.

This correct answer rate was a better result than the overall average correct answer rate of all schools that took the CBT examination.

In all the schools that took the CBT examination, the overall average correct answer rate of the question of differential and integral calculus was about 60% (main CBT examination) and 59% (additional CBT examination).

It seems that the gallery function for graphical and theoretical understanding, and video lessons and the questions that can be solved using both differential and integral calculus and formulas led to good results.

From the results of the questionnaire and the state of daily classes, it became clear that the students deepened their understanding by watching the videos at their own pace, checking the answers to the questions, and thinking about the sentences to reply to the video chats.

Further, we would like to improve about 50 class videos and post them to YouTube so that chapters can be displayed to increase viewing efficiency. In addition, using an LMS(Webclass), we are trying to check the degree of understanding through a new online test linked to each video.

For ebooks, we would like to add system numbers to differentials and integrals that connect physical quantities and laws. As an example of system numbers, in Fig.1, the first integration is numbered 1, and the second integration is numbered 2.

As a result, we would like to effectively guide students to learn the cause of their mistakes by introducing the display of system numbers in the explanations of answers to exercises and answers to online tests.

To advance our study of physics education using ebooks and videos one step further, we would like to verify the effectiveness of these efforts for deep learning.

Acknowledgements

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Practices and studies of how to answer students' questions
– try to achieve students' improvements and staff's "Work Style Reform"

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Abstract

This paper is a study and educational practice report to improve answering questions from students to improve their abilities and cut working time.

Because of the COVID-19 pandemic, staff have more tasks than before. So they should try to reduce the time for other tasks.

When students study or think something deeply, they usually need discussion with teachers, and it often occurs after lectures. Suppose that a quarter of the students want to discuss and that each of them spends 6 minutes after one lecture, the total time on the academic discussion with students (excluding lecture times) accounts for 20.6% of the total work time in a week. Therefore, it is useful to consider how to answer students' questions more efficiently to save time.

The author's conclusion is to upload discussion data to Learning Management System (for example "Blackboard Learn" and "Web Class"), this is because after uploading data, all students can read it so, logically speaking, only one discussion needs one topic (actually, of course, some students may need more) and because it is also useful for students to get reading skills better.

Next, the author thinks about how to get the discussion data easily. There are 4 ideas.

The first idea is to type a summary after the discussion.

The second one is to write and draw on paper and scan them after discussion.

The third one is to take photographs.

The fourth one is to use the interactive whiteboard (the electric blackboard).

The author tries all of them and concludes that using the interactive whiteboard was the best idea. It is because there are three advantages.

The first advantage is that it allows teachers and students to concentrate on the discussion because it can provide the data after the discussion.

The second one is its functions, for example, copying the whole screen, cutting/copying/deleting/moving letters and drawings. These make teachers explain more smoothly.

The third one is that it easily makes physical distance because its screen is wide and can expand letters or drawings.

Keywords: *Learning Management System, interactive whiteboard (electric blackboard), academic discussion with students, reading skills, Work Style Reform*

Introduction

When someone wants to consider and understand things, dialogue might be needed. Especially for students who have graduated from junior high school within a few years, it must be necessary to discuss. Therefore, they go to school to learn how to read technical books and how to think. At school, staff teach some 40 students with different backgrounds at the same time. So, it is impossible to give full explanations to each student. Therefore, learners ask educators directly what they cannot understand on their own. Generally speaking, they ask outside of their class, not during class. Then how much time do teachers need for these out-of-class questions? Let us calculate the time under the following assumptions.

[Assumptions]

- In each class, a quarter of the students ask questions outside of the class.
- Each question, there require 6 minutes.
- There are 8 classes per week per teacher.
- There are 40 students in each class.

Under these assumptions, the weekly out-of-class Q&A time is [6 * (40 / 4) * 8 =] 480 minutes. At the National College of Technology (KOSEN), the prescribed working hours are 7 hours and 45 minutes per working day, and the working days per week are 5 days. In other words, the prescribed working hours per week are 2325 minutes. Therefore, about 20.6% of the regular working hours in a week are spent answering out-of-class questions.

By the way, because of the COVID-19 pandemic, staff have more tasks than before. For these additional tasks, they should try to reduce the time for other tasks. Answering out-of-class questions from students needs much time, therefore it is useful for staff to consider how to answer these questions more efficiently to save time. In addition, it is useful for students to consider that. This is because shortening or reducing the Q&A time while maintaining the quality of the answering lets teachers spend more time for the classes, and the simple answer allows students to understand easily.

The author searched previous research. He found [1, Jun MADA], but this research is for remote classes, not for answering questions from students. Therefore, he tried to think of methods and ideas for Q&A.

Thinking methods and ideas

As a method to shorten or reduce the Q&A time, the author used a method similar to FAQ, that is, "teachers write frequently asked questions and their answers in advance and show them for all students, and ask them to read these FAQ first if possible when they have questions.". Since it is difficult to determine which questions are "frequently asked questions" and which ones are not, the author decided to treat all the questions from students as "frequently asked questions". And he put them in the Learning Management System (hereinafter referred to as LMS) which the students and teachers ordinarily use. So, all the answers to the questions from students must be transferred as electronic data.

This method also has two advantages for students. The first one is that they can search for answers to their questions anytime and anywhere. The second one is that their reading and comprehension skills will improve. The answers were written for other students, so he or she should read and think about them. And if he or she cannot understand them, he or she should inform their teachers what is OK and what is not OK and ask them to understand. Therefore, this method also has educational advantages for students.

Next, the author thought about how to get the discussion data easily. There were 4 ideas. He tried all of them and found the advantages and disadvantages of each idea. They are shown below. In addition, there are effective conditions for each idea.

The first idea is to type a summary after the discussion. This idea is to summarize the questions and answers by typing after the discussion. The teacher takes notes while answering questions, and after the discussion, he looks at the notes and summarizes them.

[Advantage]

- ➢ It can be carried out without making the students wait.
- ➢ It can summarize questions simply

[Disadvantage]

- ➢ A considerable amount of time is required (in addition to the answering time).
- ➢ It needs to summarize as soon as possible not to forget the discussions.

This idea is effective when the number of questions is a few and there is already a certain amount of "FAQ" (that is when there are few new contents to be added while answering questions).

The second one is to use A4 size papers. When the teacher explains, he writes and draws on A4 size papers so that he can scan them and upload them to the LMS after discussion.

[Advantage]

- ➢ It can be carried out without making the students wait.
- ➢ It can get the data for LSM easily (only scanning or photographing the papers).
- ➢ It requires nothing but a scanner (or a digital camera), that is, it can do on a low budget.

[Disadvantage]

- ➢ It requires a desk or something to write and draw on paper.
- ➢ When two or more students listen to the answers at the same time, some may not be able to see the paper, or some may have to read from different directions
- ➢ It makes teachers have a certain number of sheets of paper at any time.
- ➢ The distance between the student(s) and the teacher tends to be close (need to be careful because of the COVID-19 pandemic).

This idea is effective when one student discusses one teacher. Therefore, it is effective when a tutor manages questions.

The third one is to take photographs. When the teacher explains to students, he writes and draws on a blackboard or a whiteboard, and before erasing them, he takes photographs of them with his digital camera.

[Advantage]

- ➢ There are no troubles if two or more students listen to the answers at the same time. (compare to the second one)
- ➢ It is easy to maintain a certain distance between the student(s) and the teacher. (more appropriate than the second one in terms of the COVID-19 pandemic)
- ➢ It can get the data for LMS easily. (just change the file name)

[Disadvantage]

- ➢ It requires a blackboard or a whiteboard.
- ➢ When the teacher takes a photograph, the students must wait. They are interrupted in their thinking.
- ➢ Teachers must have a digital camera at any time.
- ➢ It is necessary to be careful about personal information (such as information about the students and the school, especially near the bulletin board).

This idea is effective if staff cannot carry the fourth one. It is because there are few changes from the existing work, as it is just adding taking photographs, and uploading them.

The fourth one is to use an interactive whiteboard (an electric blackboard). After discussion, it offers the discussion data.

[Advantage]

- ➢ It can be carried out without making the students wait.
- ➢ There are no troubles if two or more students listen to the answers at the same time. (compare to the second one)
- ➢ It is easy to maintain a certain distance between the student(s) and the teacher. (more appropriate

than the second one in terms of the COVID-19 pandemic)

- It can get the data for LMS easily. (just change the file name)
- Teachers do not have to have papers, digital cameras, and so on. (compare to the second one and the third one)
- It offers only the data written and drawn at the time of explanation. (personal information is not included. compare to the third one.)

[Disadvantage]

- An interactive whiteboard is required. It is very expensive and if another person uses it, the teacher cannot discuss the students.
- (Of course, some interactive whiteboards can move,) discussions can only be carried out near the interactive whiteboard.
- Data saving may fail due to power outages, so the teacher needs to save frequently.

This idea is effective if staff can use an interactive whiteboard freely.

Practices and their data

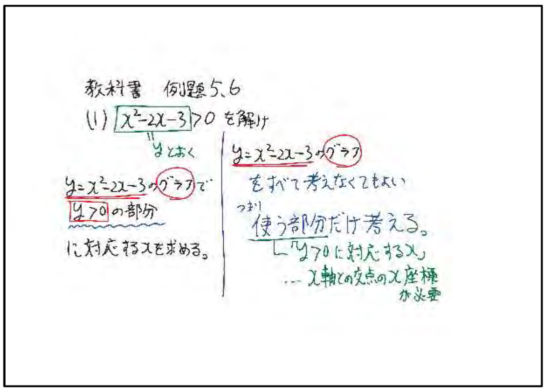
In this section, there are the practices and data of the author's ideas. The first content is the data for the usefulness of uploading on an LMS. The LMS which the author uses ("Blackboard Learn") gives the access data. From April to August 2022, the author uploaded 178 Q&A data. The LMS offers the access data of these 178. He calculates the mean times of the accesses and it showed 370.5 accesses per one Q&A data on average. This means that over 100 questions from students on one topic are solved by themselves. It is evidence to support the usefulness of uploading on the LMS.

The second content is the practices of the idea. As informed in the previous section, the author tried all four ideas. The readers easily imagine the practices of the first idea, second one, and third one. The practice of the fourth idea is shown below.

First, the author shows the main method among the specific ways of using an interactive whiteboard for answering questions.

1. Listen to the exercise number from the student and write it on the upper left of the interactive whiteboard. As a general rule, do not enlarge, reduce, move, or delete this description.
2. Listen to questions from students and write or draw them on the interactive whiteboard using the black pen mode. At that time, what is written or drawn is limited to those in the exercise sentence and what they say.
3. Add (write or draw) the things which are lead from what is written or drawn at the previous step in (a) different color(s) (for example, calculations, reasoning, angles, lengths of sides, what you can say from the definition of words, using some theorems, and so on.).
4. If the students understand, change color(s) to black if possible.
5. If no space is left or if needed, make a copy of the current screen. The copy screen is on the next page. On the new page, keep the exercise number and what is needed to think. Then erase the left other than the last calculus (or thinking). The last calculus (or thinking) is put in empty spaces, especially near the beginning of the line.
6. Repeat the previous three steps until the student is satisfied with the explanation. In case of power outages, save the screens temporarily when the students are thinking.
7. When the students are satisfied, save all of the screens as one electronic file. The interactive whiteboard creates a PDF file.
8. Clear the screens and move on to the next question.

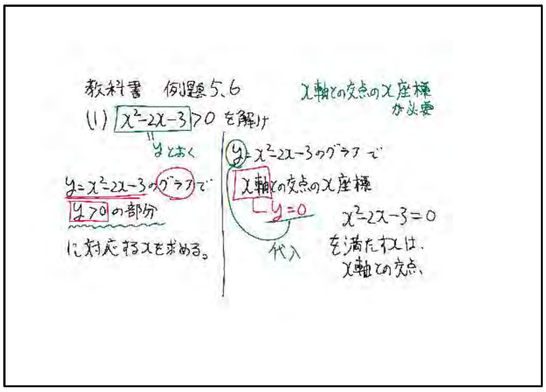
Next, the author shows the practices. There are two figures below. These are an example of the file which the interactive whiteboard created. Figure 2 is created from a copy of Figure 1. The reader compares them and realizes that Figure 2 is made of Figure 1, that is to say, copy the whole of Figure 1, erase some sentences, circle, and underlines, copy a part of the last sentence, move and change the color of it, move the whole of the last sentence and write some new sentences. In other words, the functions of the interactive whiteboard help teachers to explain more easily.



教科書　例題5.6
(1) $\boxed{x^2-2x-3}>0$ を解け
yとおく
$y=x^2-2x-3$のグラフで
$\boxed{y>0}$の部分
に対応するxを求める。

$y=x^2-2x-3$のグラフ
をすべて考えなくてもよい
つまり
使う部分だけ考える。
「$y>0$に対応するx」
…x軸との交点のx座標
が必要

Figure 1: Source screen



教科書　例題5.6
(1) $\boxed{x^2-2x-3}>0$ を解け
yとおく
$y=x^2-2x-3$のグラフで
$\boxed{y>0}$の部分
に対応するxを求める。

x軸との交点のx座標
が必要
$y=x^2-2x-3$のグラフで
$\boxed{x\text{軸}}$との交点のx座標
$y=0$
代入
$x^2-2x-3=0$
を満たすxは、
x軸との交点、

Figure 2: Copied and modified screen

There are other two figures below. These are also an example of the file which the interactive whiteboard created. Figure 4 is created from a copy of Figure 3. The author wants to keep the screen of Figure 3 so he copies it. This is because after teaching in Figure 4, he goes back to the previous page (Figure 3) and suggests the student write and draw what she understands. If she understands, she can do them. If she writes and draws wrongly, undo them and challenge them again and again. In other words, the functions of the interactive whiteboard help students to think as much as they want.

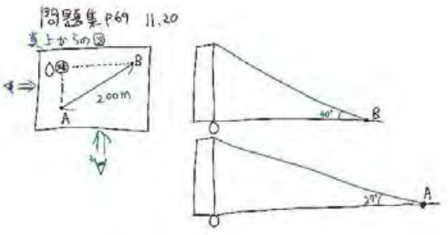


Figure 3: Base screen

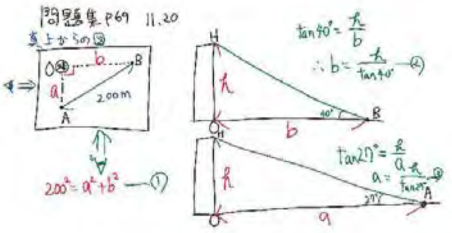


Figure 4: Explained screen

Conclusions

The author concludes that uploading Q&A data on an LMS is a good idea. And the author concludes that to create Q&A data, using the interactive whiteboard was the best idea. It is because there are three advantages.

The first advantage is that it allows teachers and students to concentrate on the discussion because it can provide the data after the discussion. There are no interruptions so it offers better time for students.

The second one is its functions for writing and drawing. For example, it can undo and redo writing or drawing, copy the whole screen, cut/copy/delete/move letters and drawings on its screen and change their colors. As is shown in the previous section(the main method among the specific ways of using an interactive whiteboard for answering questions), these functions make teachers explain more smoothly and make students understand more easily. Therefore, they can reduce discussion time effectively.

The third one is that it easily makes physical distance because its screen is wide and can expand letters or drawings. During the COVID-19 pandemic, these functions are more important than ordinary.

Using a Learning Management System and an interactive whiteboard makes academic discussion with students more effective. Q&A data uploaded on the LMS improves students' reading skills. And using the interactive whiteboard is useful for making physical distance, for students studying, and for cutting teachers' working time. These are the conclusion of this paper.

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Pedagogically Driven Topic Extraction on Module-Based Student Survey Data

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Abstract

Institutions of higher learning collect surveys on course modules so that students can provide open-ended qualitative feedback. However, it is challenging to fully comprehend major concerns of students from a pedagogical point of view when reading hundreds of seemingly diverse student responses. Generally, it would be more useful to have qualitative feedback framed according to a pedagogical-driven taxonomy which is well understood by educators. The taxonomy includes sub-topics for assessments, projects, assignments, content, teaching plan, pace, difficulty, and student preferences. For example, a sub-topic for student preference can be about dissatisfaction with specific methodology such as e-learning or flipped classrooms. This paper explores the use of Large Language Models (LLMs) to automatically tag students' qualitative feedback. LLMs attain good model outcome with task-agnostic fine-tuned performance learning. This ensures that fewer samples of survey responses for each topic in the taxonomy, are required for the LLM to learn, relative to non-LLM approaches. Using the proposed methodologies, the qualitative responses can now be automatically tagged and organised in pedagogically meaningful topics and further merged with other relevant student information to be rendered visually as dashboards for easy understanding. Dashboards are foundational in helping stakeholders improve their course design, student engagement, and pedagogical approach, across the different semesters. The stakeholders can come from a diverse group such as lecturers, pedagogy designers and program administrators.

Keywords: s*tudent survey, topic extraction, pedagogical taxonomies, large language models, natural language processing, dashboarding, learning analytics*

1. Introduction

Student surveys are de-rigueur for assessing the teaching effectiveness and student learning in Institutes of Higher Learning. Survey results are analysed without much difficulty when responses are structured into meaningful categories such as 'agree/disagree' or according to a Likert scale. What is more difficult to analyse are the student responses to open-ended questions like 'What are the possible areas for improvement?'. Verbatim feedbacks are rich in information because this data represents the voices of the students.

Analysis of open-ended qualitative data is complicated due to the messiness caused by 3 main factors. First, the responses are typically large in volume ranging from a few hundred to a few thousand entries, depending on the context of the analysis. Second, a response can be overwhelming to comprehend particularly when a student has a long commentary consisting of a litany of topics. Third, student responses are very diverse in nature as different students have varying preferences, aversions and needs.

Technically, it is not impossible to analyse such data. A data analyst can add structure to this messiness by methodically tagging each student's comment to a relevant topic. Such data entry methods are infeasible for an organization. This lack of structure in the analysis meant that course surveys are best left to course lecturers who will form their own overall impressions of student learning needs, usually by looking out for responses that stood out when browsing through the comments.

We propose letting AI (Artificial Intelligence) tag pertinent student comments to relevant topics as well as tag less useful comments as non-comments. The tagged data can then be organized in a visual dashboard, to allow interested stakeholders to identify the major areas of student concerns readily. The dashboard user can focus on the areas of interest by drilling-down on the more salient topics, to read the verbatim comments. Educators with different background in terms of responsibilities and pedagogical needs can use the dashboards for better insights on the areas of student concerns about the subject. The insights gained help the educators to take the appropriate actions on the pedagogy and instructional design of the subject in the next course offering.

This paper is structured as follows. We first present as Section 2, Background of the survey. Section 3 is the Literature Review, highlighting work that were done in this area previously. Section 4 details the methodology and the data. A description of the survey data from Temasek Polytechnic is made without compromising the institution's data governance policy. This section also describes the issues typical to such survey data. The taxonomy as well as how this taxonomy was developed is elaborated. This section then describes the data preparation efforts primarily in terms of annotating the text, and the algorithms used for developing the AI model. Section 5 presents the results and discussion. These include the identification of the best algorithm and a sample dashboard. Section 6 presents the conclusion and Section 7 ends with areas for future work.

2. Background

This study involved student survey response from the School of Informatics and IT (IIT), Temasek Polytechnic, The Teaching Evaluation & Subject Survey is administered at the end of each semester and all students are strongly encouraged to respond to the survey for each of their course module. The Subject Survey consists of five questions with Likert-scale responses and two open-ended questions. More specifically, the open-ended question of interest was: "Identify area(s) in which the subject could further improve, to better support student learning".

3. Literature Review

The use of Natural Language Processing (NLP) techniques to classify responses to open-ended student surveys for dashboarding purposes using traditional Machine Learning (ML) was proposed by Gottipati et al. (2018).

Large Language Models (LLM) are now considered state-of-the-art over traditional machine learning approaches proposed above. Fine-tuning a pretrained LLM such as BERT (Devlin et al., 2019) to specific tasks has produced state-of-the-art results in text classification, due to its ability to differentiate semantic nuances in human expressions.

This approach allows the conception of more granular topics, in the taxonomy development phase.

4. Methods

The work done on the student survey could be broken down into five stages:

4.1. Data Exploration

The dataset obtained from the survey was considered small for NLP purposes. The limited size of the dataset was further constrained by the fact that majority of students did not provide any valid comments to the open-ended question as shown in
Figure 1.

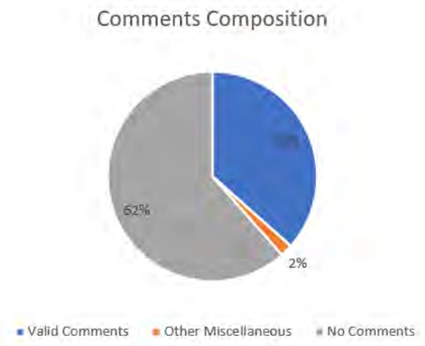


Figure 1: Composition of Relevant and Irrelevant Comments

Only 36% of the comments were classified as 'Valid Comments'. The biggest group of non-valid comments included 'No Comments', associated with responses such as: blank, "NIL", "N.A.", "idk (I don't know)", "Can't think of anything" or something of the nature that is positive like "This course is good. I have nothing further to add" or "The lecturer is great".

The remaining group of non-valid comments belonged to the "Other Miscellaneous" category. These comments were limited in value due to the following reasons:

a) Hard to interpret or are non-actionable. Examples are: 'lesson', 'teaching environment', 'hh', where such comments were deemed as too cryptic to be useful.
b) Non-systemic in nature. This refers to student's concerns that is very rare and non-repeatable across other different student cohorts and communities. Some examples of such comments are: "more stern and louder", "XYZ topic being taught does not appear in the examination", "prefer to focus more on XYZ topic and drop ABC topic"

4.2. Taxonomy Development

The main component enabling the survey data to actionable use, is the establishment of a good taxonomy that leads to a pedagogical outcome in the areas of content, assessments, assignments, pace, difficulty, instructional levels, and student preferences. The following rules were followed when developing the taxonomy:

a) Close consultation with the operational users of the taxonomy, such as course chairs and lecturers, to ensure that student concerns could be mapped to a pedagogical need.
b) Sufficient granularity of topics to facilitate analysis but not too high such that it is unable to stand by itself as a class. For example, in certain comments, it is not possible to know if a student was referring to an assignment or a project. So "Assignments, Projects Not Enough Time" would be a better topic. To have a distinction between assignments and assessments, a separate topic "More Time For Assessments/Test" was also introduced.

Initially, unsupervised Machine Learning (ML) was used to hasten the development of the taxonomy. Unsupervised ML essentially requires no human intervention in the topic discovery process. Techniques such as Latent Dirichlet Allocation (LDA) or BERTopic (a hierarchical clustering algorithm that makes use of embeddings from BERT) were used. However, unsupervised ML did not work well due to two reasons. First, the dataset is highly unbalanced in nature. Some topics could be attributed to a few hundred students while others could only be attributed to a handful of students. Topics with low attribution had low chances of discovery. Second, the diversity of what was said in the comments was huge and it is important to distinguish the useful comments from the less useful ones (i.e. noise). Unsupervised ML is highly susceptible to noise. In the end, it was not practical to use unsupervised learning. Human knowledge and intervention were needed to develop the topics for the taxonomy and to prepare the data.

An examination of valid comments led to the development of the following taxonomy of 59 topics:

- Assignments Close Deadlines.
- Assignments, Projects Not Enough Time
- Assignments/Assessments Time Consuming/Workload
- Assignments/Assessments Are Too Difficult
- Better Content Organization
- Change Component Weightage
- Class Scheduling Issues
- Clearer Or Better Labsheet
- Coding Related Challenges
- Content Less Wordy/More Concise
- Focus On The Basics, Knowledge Gap Exists
- Group Mixing Issues
- Hard to Follow, Understand-Concepts
- Issues With Group Work
- Issues With Practicals and Assessments
- Issues With Presentation
- Issues With Self-Learning
- Issues With E-Learning
- Issues With Flipped Classroom
- Issues With Subject Teaching Plan
- Lecturer Go Through Materials Together
- Lecturers More Feedback/Consultation
- Lecturers Revise More
- Lesson Times Are Too Long
- Lesson Times Are Too Short
- Marking Rubric Is Unclear
- More choices In tools, techniques, projects
- More Engaging/Interactive Lecturers
- More Face To Face (F2F) Contact Time
- More Gamification Activities
- More Group Work /Discussions
- More (Home Based Learning)
- More Help, Clarity On Projects, Assignments, Tests
- More or Better Guides/Notes/Slides
- More Or Better Videos
- More Practice/Hands-On/Lab Activity
- More Quizzes/Mock Test
- More Relevant Content
- More Templates for Projects/Assignments
- More Theory To Build Foundational Understanding
- More Time For Assessments/Test
- More Time For Labs/Practice
- More Time/Attention On Certain Topic
- Need Explanations
- Need More Examples
- Prefer To Be Non-Graded Subject/Component
- Provide Answers To Aid Learning
- Provide Summary/Cheatsheet
- Release Materials and Info Earlier
- Subject Content Not-Up-To-Date, Buggy
- Subject Is Too Hard
- Subject Is Too Simple
- Teaching Pace Can Be Faster
- Teaching Pace Can Be Slower/Reduce Workload
- Technical Issues With Tools,Techniques
- Too Basic, More Depth On Certain Topic
- Too Boring
- Too Much Content
- Uninterested In the Subject

4.3. Data Preparation and Annotation

Manual effort to label each student's comment with an appropriate topic, was required to prepare sufficient high-quality data for the AI model to learn from. The following rules were followed for data labelling:

a) Each student comment was assigned a label according to the topic defined in the taxonomy.
b) Extraneous phrases or sentences in the comments not relevant to any topic in the taxonomy were removed.
c) Any single sentence in a comment resulting in multiple topics, were treated as follows:

    - Disambiguation by separation. If a student was talking about two different topics within a single sentence, it would be helpful to disambiguate the sentence by separating that sentence into two entries each with its own relevant topic. For example, sentence like "I find the lessons boring and that there isn't enough time to finish the practical test", could be split into two entries - "I find the lessons boring" and "I find that there isn't enough time to finish the practical test".
    - Multi-label scenario. If a student were talking about two different topics within a single sentence and topics are related to one other, that sentence should be preserved whole and tagged with multiple labels. To illustrate, "The slides could show more examples of students work from the previous batches", is a sentence which should be preserved whole. It would be provided two labels namely, "Need More Examples" and "More or Better Guides/Notes/Slides"

d) Student comments labelled as "Other Miscellaneous" were omitted for model training.

4.4. Model Development

Candidate machine learning models were adapted from Tunstall,et al. in Dealing With Few To No Labels (2022). The listing of the algorithms is sorted by the levels of computational cost, from the least to the most expensive. The aim was to understand the trade-offs between the model performance and the computational cost in model development and use. The use of LLMs would require the use of specialized hardware such as Graphic Processing Units (GPUs).

a) Naïve Bayes Classifier is a relatively simple probabilistic classifier that computes the probability of texts belonging to a class. This classifier's drawback is the simple assumption that relationships between words in a sentence does not matter, thereby losing the ability to differentiate text with contextual and semantic nuances.

b) Zero-Shot Machine Learning uses a pre-trained LLM model to figure out the relationship between the topic label and the student comment based on semantics. This method does not require any manual effort for text annotation as the model need not train on the text to learn about that relationship.

c) Nearest Neighbour Embedding. This approach uses a LLM to translate a piece of text into representative embeddings. The nearest neighbour algorithm then uses these embeddings to find a boundary space which encapsulates all student comments within a specific topic, as provided by the topic label.

d) Fine-Tune BERT. BERT is a LLM which can capture the contextual semantics in sentences well. BERT is fine-tuned when it is trained by learning the relationship between the annotated labels and text.

All the models were developed by adopting 70% of the data for training, 15% for validation and 15% for testing. The micro and macro averaged F1 scores were then calculated for each model on the test data, to estimate the model performance for different models.

4.5. Dashboard Development

A prototype dashboard design was created to enable practical use of the model. The survey also included another question: "Overall I am satisfied with this subject". The dashboard links the data on student satisfaction to the topics. The stakeholders wanted to understand the concerns of students with low satisfaction rating.

5. Results and Discussion

The model performance improved when developing the models on a successively bigger datasets with more training examples as shown in Figure 3 and Figure 4. By referring to the F1 scores which denotes how good the model is, the Fine-Tuned BERT model is the best performing and the Naïve Bayes Classifier is the least performing model.

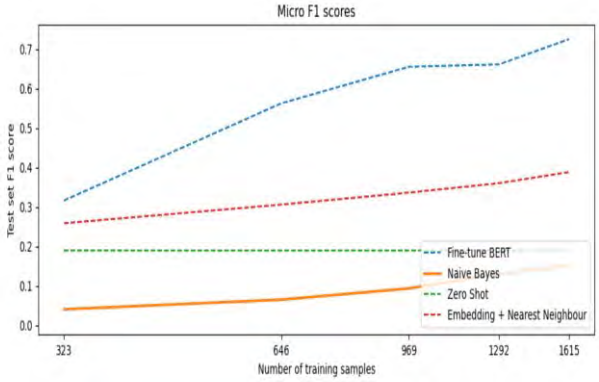


Figure 2: Model Performance based on Micro Avg F1 Scores

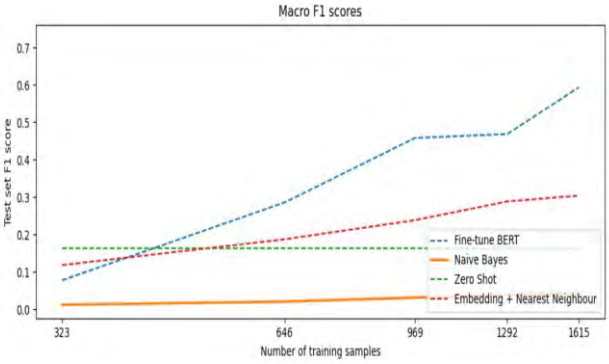


Figure 3: Model Performance based on Macro Avg F1 Scores

Table 1 shows that topics with more labelled instances for the models to train on (i.e., > 20) have significantly higher F1 score denoting better model performance.

Table 1: Macro Average F1 Scores of Topics with Few Labels and Many Labels

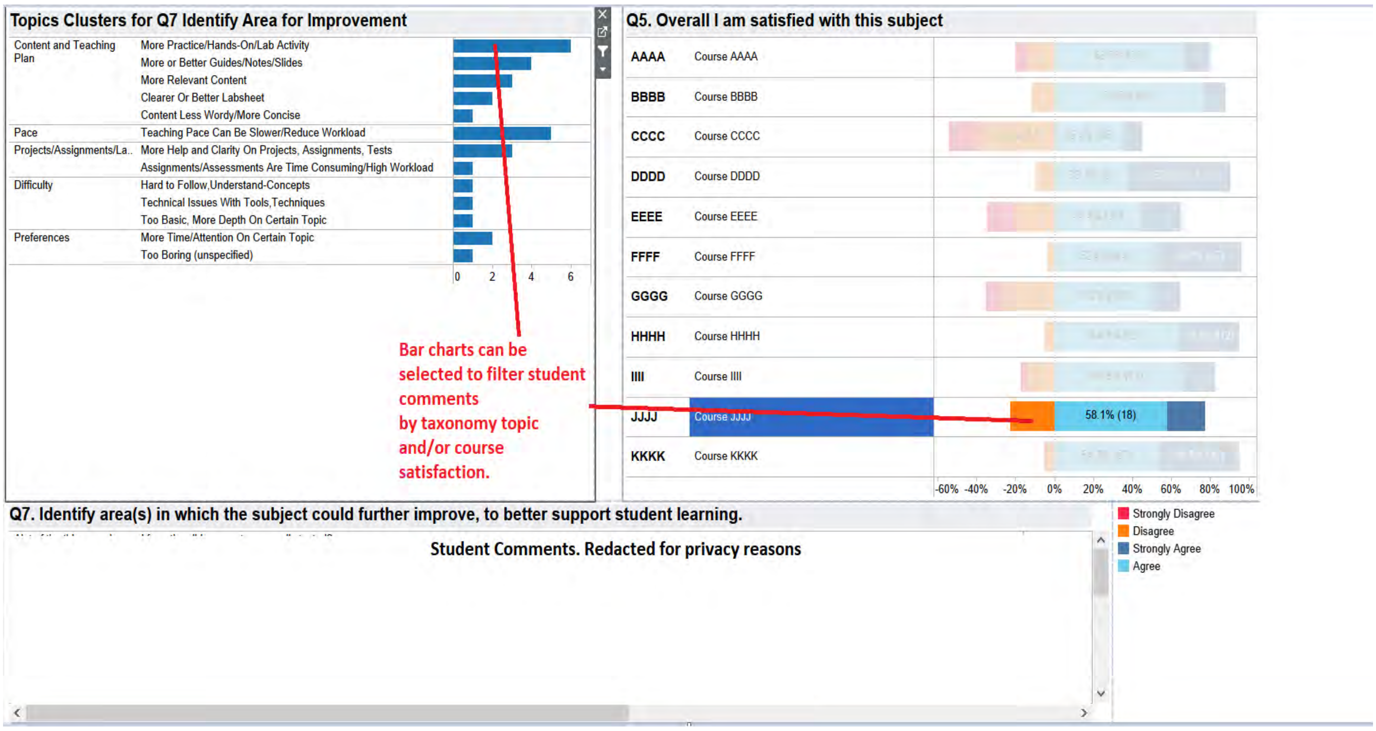
Avg F1 score of topics with many labelled instances	0.707
Avg F1 score of topics with few labelled Instances	0.407

The fine-tuned BERT model was given a threshold for the prediction probability at 0.5. Each comment was parsed into sentences for sentence level prediction and the following student comment (as illustration) was used to test the model:

"I could not run my code as the versions given in the lessons are outdated. I wish that the deadline for the final project could be extended by a week as I don't have enough time. Some my group members did not contribute much to the project, and I have to do most of the work"

The model was able provide the following tags:

- Assignments, Projects Not Enough Time
- Issues With Group Work
- Coding Related Challenges
- Subject Content Not-Up-To-Date, Buggy



Bar charts can be selected to filter student comments by taxonomy topic and/or course satisfaction.

Figure 4: Dashboard linking topics for Q7 and Likert scores of Q5

Figure 4 provides a concept design of how a dashboard prototype can provide insights to improve student satisfaction by linking satisfaction levels with student concerns. The insights are for illustration only. A dashboard user could select Course JJJJ, followed by the orange band beside the course listing. This action zooms in on students with low course satisfaction in Course JJJJ. The foremost topic after zooming in, is shown as “More Practice/Hands-On/Lab Activity”. The user could then select this foremost topic to zoom in on all the verbatim comments associated with that topic.

6. Conclusion

Data preparation proved to be the first hurdle requiring human understanding to determine initially which comments were useful or were irrelevant. The next hurdle was to label the relevant comments with the appropriate topic.

There are different NLP techniques in use for topic extraction. This paper identified the fine-tuning of BERT as the most suitable approach to map student comments to a pre-defined taxonomy.

Even though this technique required higher computational expense to train and to use, it offered exceptional model performance.

The above technique showed the possibility of using AI to label student survey data for dashboarding, to be available to stakeholders interested in monitoring student concerns according to a pedagogical definition, given the taxonomy.

7. Future Work

We wish to explore the use of various active learning strategies to keep the AI model relevant and up to date in line with the evolving needs of future cohorts of students.

To improve the model performance for topics which have fewer labels due to fewer student comments, the use of few-shot learning as suggested by Tunstall et al. in Efficient Few-Shot Learning (2022) and data augmentation with CHATGPT as suggested by Dai et al. (2023).

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Mathematical attitude and the liberal arts

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Abstract

One of the reasons for studying mathematics is to acquire the ability to think freely.

In mathematics, one is free to formulate hypotheses as long as they are consistent (called axioms in mathematics). For example, in non-Euclidean geometry, the sum of the interior angles of a triangle can be greater than or less than 180 degrees. At first glance, this may seem counterintuitive, but it is equivalent to Euclidean geometry in terms of consistency. On the contrary, non-Euclidean geometry is an indispensable theory for the theory of relativity.

Hypothesis is not a concept used only in mathematics and science. Many hypotheses are used in our thinking, both explicitly and implicitly. Hypotheses enable us to think, but sometimes they limit our thinking.

In the former sense, a person's hypothesis is his/her worldview. In response to this positive aspect of hypotheses, we call the attitude of confronting the world with the idea that “everything is a hypothesis” the "mathematical attitude" in this study. The reason for this is that in mathematics, there is freedom in setting up hypotheses except for consistency, and all proofs of mathematical theorems start from axioms.

The latter can be freed by becoming aware of the implicit hypotheses within oneself and relativizing or abstracting them. This awareness is the essence of thinking freely. Therefore, it is an important part of the liberal arts.

In this paper, we will discuss the relationship between "mathematical attitude" and liberal arts, and report on the importance of mathematics education.

The development of technology is changing society. The great social changes that have taken place in the past cannot be separated from technological innovations. In addition, the development of technology and the development of theory, that is, changes in hypotheses, are closely related. Therefore, “mathematical attitude” is especially important in engineering education at KOSEN.

Keywords: *hypothesis, axiom, mathematical attitude, liberal arts, pedagogy, National Institute of Technology*

Introduction

This paper proposes the concept of “mathematical attitude” in response to the change in the way mathematics is understood in connection with the discovery of non-Euclidean geometry. It also discusses the effects of mathematical attitudes and the relationship between mathematical attitudes and liberal arts education.

2.1 Euclidean geometry

Euclidean geometry consists of five postulates:

(i) A straight line can be drawn between any different two points.
(ii) A terminated line can be extended indefinitely.
(iii) A circle can be drawn with any given point as a center and any given radius.
(iv) All right angles are equal to one another.
(v) (Parallel postulate) A straight line can be uniquely drawn through a given point not on a given line and does not meet the given line.

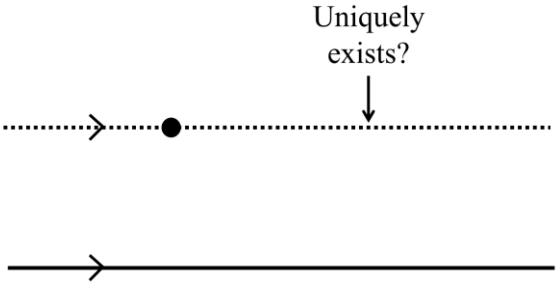

Figure 1 Parallel postulate

2.2. Relativisation of Euclidean geometry

Because the parallel postulate is non-trivial compared to other postulates, many attempts have been made to prove the parallel postulate from the other four postulates for over 2000 years. In the 18th century, G. G. Saccheri (1667-1733), an Italian Jesuit priest and mathematician, regarded the parallel postulate as a truth and argued that it cannot be proved directly. Instead, he tried to prove the parallel postulate indirectly by the method of contradiction. That is, he tried to derive a contradiction by assuming the negation of the parallel postulate. Although he derived many counterintuitive propositions from the negation of the parallel postulate, in the end he was unable to derive a contradiction.

In order to derive a proposition from the negation of the parallel postulate, we need a mind that follows logic thoroughly, not experience or intuition. In that sense, it can be said that Saccheri had a spirit that valued logic. In fact, he was also a logician. On the other hand, he could not distance himself from his belief that the parallel postulate is absolutely correct. The “contradiction” that he thought that he had been able to derive was not actually a contradiction. They are just propositions derived from the negation of the parallel postulate. It only seemed contradictory because he implicitly assumed a variant of the parallel postulate.

On the other hand, N. I. Lobachevsky (1792-1856), J. Bolyai (1802-1860), and J. C. F. Gauss (1777-1855) interpreted the counterintuitive propositions derived by Saccheri as *new theorems*. Moreover, it was a *new geometry* incompatible with Euclidean geometry. This new geometry has been called non-Euclidean geometry. These two geometries differ in intuitive acceptability but are equivalent in a logical sense. That is, if one is consistent, so is the other.

3.1. Discussion

What is the difference between Saccheri and mathematicians before him and Lobachevsky, et al.? It can be said that the difference in how to perceive the postulates. Saccheri considered them absolutely true, while Lobachevsky and others could think of them as one of many possible hypotheses. This difference gave birth to non-Euclidean geometry. Therefore, we refer to postulates and axioms here as hypotheses to emphasize their sense of being independent of experience and intuition.

This liberal attitude towards postulates is an important spirit of modern mathematics. It also has a different aspect from the scientific spirit. This is because mathematics and science have different objects. While science focuses on reality, the target of mathematics is often not only reality but rather mathematics itself. Mathematics can thus be constructed independently of reality. All that is required of mathematics is that the set of hypotheses (axiom system, a set of postulates) be consistent. As H. Poincare (1854-1912) pointed out in Poincare (1902), hypotheses in mathematics are merely *conventions*.

3.2. A new notion “Mathematical attitude”

Considering the free attitude toward hypotheses in mathematics, as mentioned above, we define the *mathematical attitude* as *attitudes facing the world based on the recognition that everything is based on hypotheses*.

All theorems in mathematics are propositions that have been proven. All the proofs can be traced back to the axioms if we trace them according to logic. Therefore, if the axioms change, the theorem that can be proved also changes completely. By the research in mathematical logic, like the axiomatic set theory ZFC, there are axiomatic systems that serve as "standards", but any axiom system is valid as mathematics if it is consistent. For example, while Euclidean geometry is the basis of our intuition about space and naive physics, non-Euclidean geometry is also a necessary theory for the theory of relativity and therefore an important set of axioms underpinning modern technology.

From this, we can extend the concept of axioms in mathematics and grasp the meaning of "hypothesis" broadly. Concepts that form the basis of our daily thinking, behaviors, and habits can also be called hypotheses. Some of these are born with us, while others are made by education, experience and upbringing, that is, by society. Rather, it can be said that the latter accounts for the majority. Moreover, some of these are conscious and some are unconscious.

3.3. What mathematical attitude tells us

Of course, we need to have many hypotheses in order to lead a daily life. In addition, some hypotheses expand the possibilities of our thinking. In this sense, the hypothesis gives us the possibility to act and think *freely*. On the other hand, there are many hypotheses which *limit* our thinking. For example, fixed beliefs, a way of thinking that clings to past successful experiences, and a way of thinking that perceives the world as a dichotomy between good and evil. In this case, we are often not consciously accustomed to such hypotheses.

In order to discover such our own hidden hypotheses, we pursue studies and interact with others who have different hypotheses. As a major premise to enable such growth, it is necessary to acquire a mathematical attitude. By adopting a mathematical attitude, we can show the following:

1. One can learn a new way of thinking.
2. More free thinking becomes possible.
3. Make it possible to communicate with a wider range of others.
4. One can acquire the spirit of equality.
5. One will be able to find happiness in everyday life.

About 1. We cannot learn other ways of thinking as long as we believe that we are unconditionally right. Here, the mathematical attitude gives us the recognition that we are not necessarily right, and that the other person is not necessarily wrong. This is because both our thoughts and those of others are based on hypotheses, and hypotheses can always be disproved. This kind of recognition enables us to have the attitude of trying to acquire the way of thinking that we do not yet know.

About 2. In order to think freely, first of all, it is necessary to become aware of (unconscious) prejudices, beliefs and values that limit one's thinking, and secondly, through the 1 above, it is necessary to relativize them by acquiring diverse ways of thinking. Mathematical attitudes also function for the former. This is because the mathematical attitude, by relativizing an idea, makes us think about what the basis for that idea is. As a result, the underlying preconceptions and values may be revealed.

About 3. If we have fixed ideas or strong beliefs, we will have difficulty communicating with others. Of course, it is important to have our own ideas and worldviews. On the other hand, by always securing the possibility of relativization, it becomes possible to improve and broaden one's thoughts through communication with others. Therefore, it is possible to communicate with various people by recognizing that there are various ways of thinking, that is, there are various hypotheses, through the mathematical attitudes. The mathematical attitude means the attitude to temporarily accept the ideas of others as hypotheses.

About 4. From the mathematical attitude, everything begins with a hypothesis. Therefore, there is no proposition that holds unconditionally. Also, once a proposition is proved in a system of axioms, it is just a theorem. It has nothing to do with who proved it or what kind of person proved it. In that sense, people are equal. In particular, one might say that they are equal under mathematics.

About 5. Our daily life is supported by the establishment of countless assumptions. In normal times, they are difficult to recognize. On the other hand, in an emergency, for the first time, we may notice the assumptions that support us. For example, the covid-19 turmoil has taught us the value of being able to meet and communicate with people and go on trips. But can we appreciate the value of everyday life without experiencing the extraordinary? Not necessarily. By hypothesizing all things in our daily lives through the mathematical attitudes, we can appreciate the fact that our daily lives exist, and we can be grateful for that. We can recognize the extraordinary of the ordinary through the mathematical attitudes. This is an important foundation for feeling gratitude and happiness in everyday life.

3.4. Mathematical attitude and liberal arts

From 1 and 2 above, we see that the mathematical attitude is relevant to liberal arts and its education. Liberal arts are a technique for becoming free, and for that purpose it is necessary to become aware of our own limitations and relativize them. In this sense, Horihata (2021) argued that the foundation of the liberal arts is the ability to abstract.

In order to abstract an object, it is necessary to first recognize the object. Next, it is necessary to have a viewpoint to abstract the object. It can be said that the liberal arts provide a perspective of abstraction backed by human history. This “viewpoint” corresponds to the “hypothesis” described in this paper.

Even with the same target, having different hypotheses will result in different information and value that can be found from the target. The result of the abstraction will also be different. In these days when countries are globalizing and values are diversifying, it can be said that being able to come and go between various viewpoints and worldviews is an important skill. Mathematical attitude underpins that ability.

By abstracting objects, we can sometimes find common structures among them. This enables communication and discussion between various people. Abstraction means discarding concepts that do not belong to the viewpoint. Therefore, for example, by noticing concepts that limit one's thinking and abstracting them away, one can think more freely.

Also, having an abstract interest means expanding the object of interest. Therefore, by making the interest more abstract, the amount of information that can be picked up increases. But it is not easy to have an abstract interest. We need to study so that we can draw abstract dreams and interests. These are done through language. In other words, the ability to use words freely in the language space is important. As I mentioned earlier, the characteristic of mathematics is that its object is also mathematics, that is, mathematics is purely a study in language space. Furthermore, mathematics can be said to be an academic discipline that explores the limits of freedom under rules, such as how freely theorems can be derived from fixed axioms and hypotheses in the language space. Therefore, in order to be free, it is very effective to explore mathematics and acquire a mathematical attitude.

4. Conclusions and future tasks

I focused on the fundamental structure of mathematics as an academic discipline, rather than simply as a discipline of logical thinking. In other words, mathematics is based on a system of axioms, and furthermore, we focused on the freedom of mathematics, in which the axioms can be chosen freely as long as they are consistent. Based on these aspects of mathematics, I defined a mathematical attitude and described the things that can be derived from it. In particular, I stated that we can free our thinking through mathematical attitudes, and that we can understand what happiness is by recognizing the non-obviousness of everyday life.

In this paper, I have discussed the relativization aspect and freedom of the mathematical attitudes. In the future, I would like to consider the mathematical attitudes and creativity, and mathematical attitudes and diversity.

Regarding the former, for example, by hypothesizing and abstracting some of the conditions of an existing structure, it is possible to relate it to other structures or create a new structure.

The latter is related to the self-referential nature of mathematics as a discipline. For sciences other than mathematics and other disciplines, the object is "outside" the discipline. On the other hand, the object of mathematics is also mathematics. Mathematics is purely a study of language. Therefore, a theorem proved by a system of axioms has its own meaning and value. In science, on the other hand, the conclusions obtained are always applied to the natural world or human society, and the meaning and value are determined by whether or not it is appropriate. Therefore, the diversity of consequences is one of the important features of mathematics.

I also would like to propose the possibility of reforming the liberal arts into a broader, more modern version through the notion of the mathematical attitudes.

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MODULE INTEGRATION TO STIMULATE CRITICAL-THINKING, INTEREST & PROFICIENCY: A CASE-STUDY IN BUILT ENVIRONMENT DESIGN & TECHNOLOGY (D&T) EDUCATION

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Abstract

Holistic building design, Integrated Design process (IDP), green-building rating and Building Information Modelling (BIM) are common terms within the built-environment discipline today. The framework of all these approaches dictates various consultants to synthesize their expertise towards achieving sustainability targets moving away from the conventional model of transferring drawings or concepts from one consultant to another. It is hence vital to step away from this traditional system starting with the education model. With 'skills' being the focus of technical education most modules are taught in isolation from each other creating perspective gaps. Experiential gaps (Bloom, 1956) within every level reduces iterative approach to address fundamental knowledge. These gaps have led to focussed learning but with disconnected perspectives. The teaching team of the diploma in Architectural Technology & Building Services (ABS), at the School of Engineering, Temasek Polytechnic has attempted to bridge these disconnections in learning gaps by the horizontal and vertical integration of knowledge and skills across various core modules. As a pilot initiative, effort was made to design projects and lab-sheets, to focus on a common authentic scenario, in this case a new building development. In another case, project timelines and deliverables were framed to drive knowledge and skill amalgamation satisfying the project needs of either module at the same time. Taken forward to the next semester, the same scenario was revisited and built-upon using a newly learnt skillset. Focused group interviews and surveys indicate critical thinking, deep-learning, and ability to inter-connect concepts were positive outcomes of the exercise. The integration of teaching materials had a greater impact on cognition than assessments, in this case projects. However, the ability of students' grasp in one module impacted their performance across all the integrated modules. Changes in groups and peers across modules and levels also impacted learning integration and project deliverables.

Keywords: *critical thinking, built environment, curriculum integration, sustainable design*

Introduction

The global directive towards sustainability have led to an increasing demand of sustainable developments in the built environment (Keeler et al., 2016). In line with this global mandate, the Singapore Green Plan 2030 sets out to achieve specific goals for the next ten years. The three key targets set out for the built environment sector of Singapore are:

- Green 80% of the buildings by 2030
- 80% improvement (from 2005 levels) in energy efficiency for best-in-class buildings by 2030
- 80% of new developments to be Super Low Energy (SLE) buildings by 2030.

Conventional building design approach buildings as an isolated object, yet each of them is comprised of various systems impacting each other. However, sustainable designs deal with much broader perspectives and enormous complexities. These include fulfilment of green building objectives/criteria, involvement of multiple stakeholders with specializations, as well as creation and application of innovative solutions within the proposal. To address these complexities, built environment professionals have developed and practice concepts such as systems thinking (Checkland, 1981), Integrated design process – IDP (Reed, 2009), and software-based technologies to share information through Building Information Modelling – BIM (Eastmen et. Al, 2011). As a common denominator, all the approaches intend to integrate knowledge and skills by promoting iterative decision-making through critical thinking and innovation.

The main purpose of polytechnic education is to prepare students for the workplace. It is hence vital that the education system for built environment-based disciplines fosters similar integration of knowledge to mimic the need of an inter/intra-disciplinary workplace to achieve sustainability targets. Taking the case of a typical student at present, he/she is equipped with knowledge, skills, and attitude to carry out tasks as an architectural or engineering assistant/ technologist including the 'knowing how' that is necessary for the job description. However, it not necessarily includes the 'knowing why' of the task addressing complex issues that impact the overall sustainability performance of the building.

To overcome such challenges inductive teaching methods have been highly adopted within the polytechnic education system. The literatures are replete with examples of inductive teaching encouraging higher levels of student cognition (Felder and Prince, 2006) and confidence during design innovation (Aditomo et. al., 2013). In most cases instructors adapt their lecture, tutorials, and laboratory courses in ways that present students with more open-ended or design-based challenges. These pedagogies help learners to increasingly cluster concepts in their mental models, forming direct links between concepts, speeding up the retrieval process (Boshuizen, 2003). Few projects found in literature, compel students to work systematically understand and apply their engineering skills across their curriculum to design work. Sheull (1990) argued that though someone familiar with the subject (a lecturer or expert) sees an organizing structure with interrelationships among various parts of the curricula, it does not mean that a novice learner makes similar connections. Tasker (1980) also highlights this gap in his findings that lessons are perceived by students as isolated events, while to the teacher they are parts of a related series of experiences. This gap has been experienced by most of us during final-year projects as project supervisors, the task being to integrate learning across curricula to develop a product or solution.

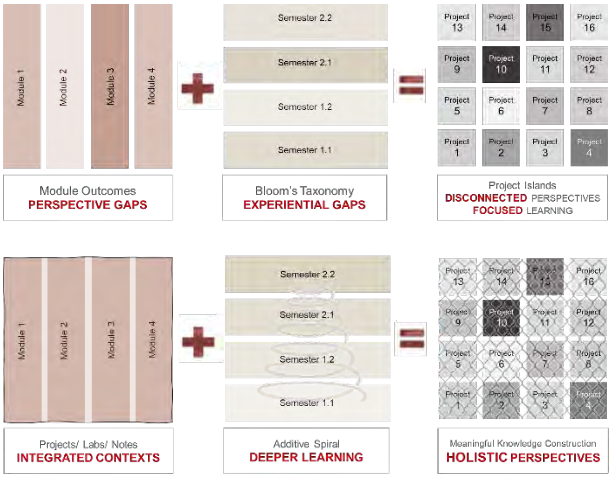


Figure 1: Current problem with the proposed framework for module integration

The paper shares a pilot attempt by Diploma in Architectural Technology & Building Services at the School of Engineering, Temasek Polytechnic, to bridge disconnections in learning gaps in the course curriculum, in particular, core modules related to the knowledge and skills of the built environment sector. The teaching team have taken an initiative to integrate knowledge and skill by developing lab sheets and projects addressing common building scenarios to cultivate a holistic perspective as demanded by the sustainable building industry, the future work-environment of graduates. Figure 1 graphically represents the problem and the proposed integrated framework.

Aims and objectives

Temasek polytechnic adopts Practice-based education (PBE), an outcome-based curriculum whereby the learning process has been designed to help students develop relevant skills, knowledge, and attitude which they are expected to apply and perform at the workplace. The objective of this paper is to understand the implication of the proposed module integration on these desirable graduate outcomes built upon the K-S-A (Knowledge-Skills-Attitude) framework. KSA are the abilities and characteristics that enable a job holder to accomplish the activities described in a task statement (Quinones, Ehrenstein, 1997). Theories of cognitive constructivism influence the proposed framework (Wadsworth, Barry, 1996). The key terms K-S-A are defined as follows in context of this paper, based on studies of cognitive constructivism:

- *Attitude* – Attitude is driven by meaningfulness established from prior experiences. Motivation to learn, self-efficacy, perception on ability to tackle complex scenarios with open-mindedness and confidence to identify alternative solutions.
- *Knowledge* – To make sense of experience. Ability to understand concepts by constructing relationships and studying implications of one concept/module over another. Perceiving the big picture for reasoning and decision making.
- Skills - Capabilities being developed by repeated hands-on experience. With skills, one can apply their knowledge and understanding in a demonstrable way establishing procedure linkage.

The aims of the study or the research questions to identify the impact of module integration on learner :

1) Attitude - Do students develop an increased interest towards the built environment industry ?
2) Knowledge - Do students make connections across modules enhancing their critical thinking capacity ?
3) Skills - Do students increasingly explore the tool (repetition) building their capabilities. ?

Implementation

The diploma in Architectural Technology & Building Services is a three-year course within the School of Engineering with the final year dedicated towards the cap-stone or major project and industry internship to cultivate a spirit of work-readiness amongst graduates. Diploma-core subjects form the crux of semesters one to four in the first two years, the target-bed for vertical and horizontal integration. The integration of the project across modules was carried over a span of 16 weeks including two weeks of term-break and a week for term-tests. modules are assessed separately for their respective syllabus-based learning outcomes. The outcomes of the modules are independent of each other.

Module integration using project scenarios: Three subjects were chosen for the pilot implementation. Individual module focus includes BIM (Architecture) skills, fundamentals of green building design and BIM (Mechanical, Electrical and Plumbing) listed in Table 1.

The subject delivery, semester and project objective have also been included. The modules A and B run in parallel during the same semester beckoning horizontal integration of projects while Module C is conducted in the following semester entailing vertical integration.

The project-scenario remained the same across the modules – Proposal for an Eco-hostel at Temasek Polytechnic campus. The spatial requirements, Gross Floor Area (GFA) and site for all the project-scenarios were crafted as a team and repeated in the individual module project briefs.

A typical building design process may be broken down into three-stages prior to construction – Concept or pre-design with site analysis including preliminary envelope massing options; schematic design taking forward the chosen massing for an iterative analysis on performance and costs; detail or technical design towards construction tender. The scope of the project mirrors the process carried out during the 'concept-design' stage of a green-building design process adopted in industry practice. The final product is ready for handover to the schematic design stage thereby taken over to Module C in the following semester. The vertical integration includes design review for the implementation of Mechanical, Electrical and Plumbing (MEP) systems and recommendation of spatial changes to accommodate these building services. As engineering BIM technologists, students learn and propose a MEP system along with clash-detection ready for valuation and performance appraisal.

Module integration in coursework (practical labs): Singapore's thrust towards a green and digital economy, drives the need for skill development in 3D-modelling and performance simulation of buildings. An attempt was made to revise lab-sheets for teaching material to focus on the same building scenario across all modules that were involved in software-based skill development.

Four subjects, module C, D, E and F within the year 2 curriculum, were targeted for this integration. Module D was focused on skill development for construction drawings, Module E on passive design performance, Module C on modelling skills for an MEP engineer and Module F on energy or performance of active systems in a building. The key aspects of these modules have been captured in Table 2.

The objective of the integration was to shift the focus from the need to understand the subject of study in the lab work towards skill development and contextual application. A typical office building was adopted as the subject for all the lab-sheets. Students are thus taken through a holistic experience of building design – sustainability, architectural and engineering services – not compromising the individual module-based learning outcomes. Figure 2 showcases implementation snapshots from student project work based on an integrated scenario and lab-sheets incorporating the same building across various modules.

Methodology

A mixed method research methodology integrating both quantitative and qualitative approaches was adopted in this study. The quantitative phase which employs a survey was followed with a quantitative phase or interview to complement each other for a complete understanding of the research questions. Survey results provides a general picture of learner's perception of module integration while open-ended feedback enhance those results by reasoning the perceptions.

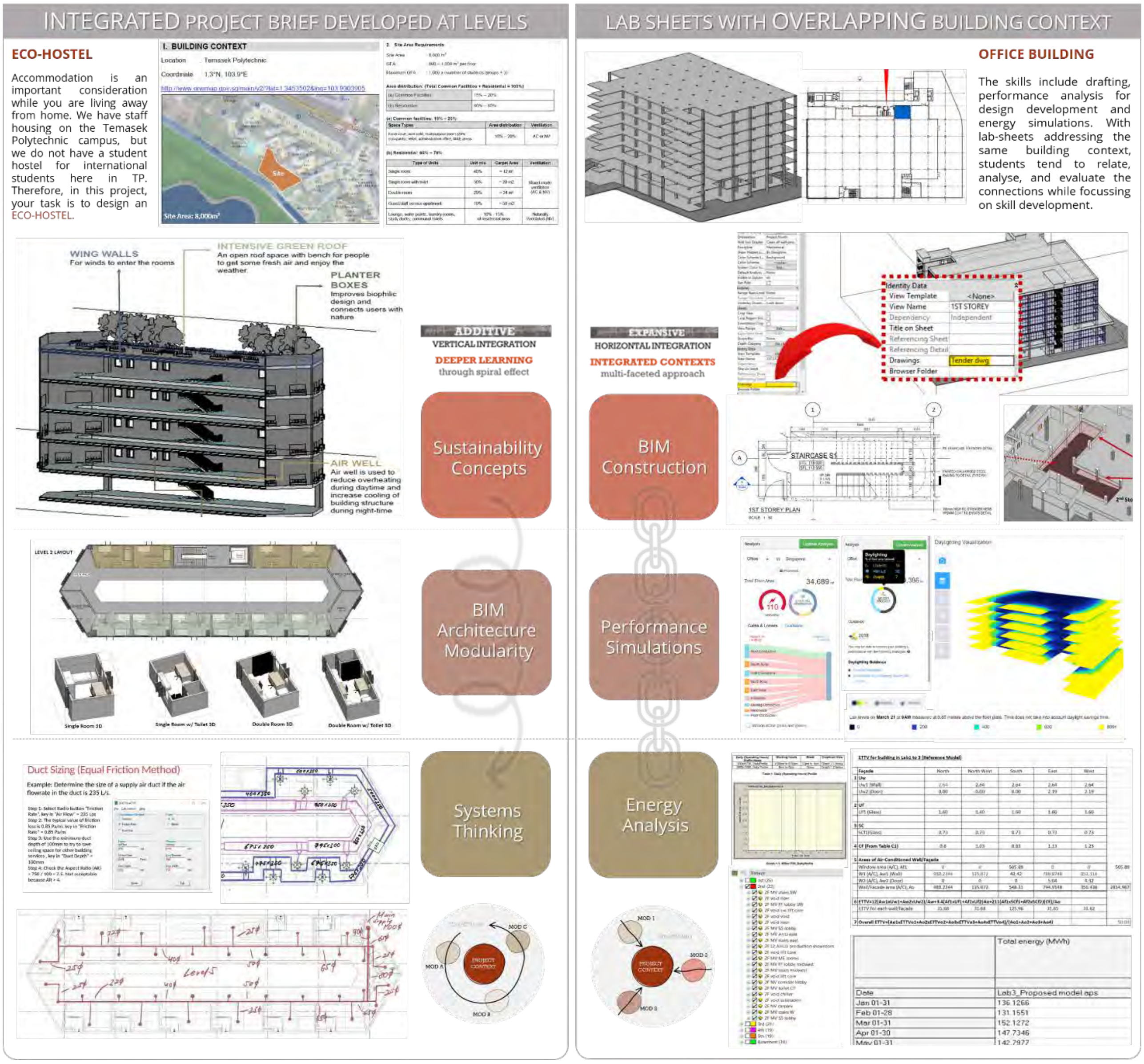
Cross-sectional surveys were conducted across both the research groups – students involved in project and lab-sheet integration. The surveys were conducted during the last-but-one week of the semester, followed by interviews the following week.

Table 1: Modules integration of project scenario

Module	Year.Semester	Expected learning outcome	Delivery
A	1.2	Skills to mass and construct a three-dimensional architectural model for schematic design	Practical labs
B	1.2	Fundamentals of sustainable building design	e-Lecture & tutorials
C	2.1	Skills to design and construct a three-dimensional MEP model for schematic design	Practical labs

Table 2: Module integration of coursework lab sheets

Module	Year.Semester	Expected learning outcome	Software
C	2.1	Skills to design and construct a three-dimensional MEP model for schematic design	Revit (MEP)
D	2.1	Skills to produce construction documentation based on authority guidelines and requirements	Revit (Architecture)
E	2.1	Passive performance simulations for green building design	SketchUp and Sefaira
F	2.2	Energy analysis and optimization through simulations	IES-VE



ECO-HOSTEL

Accommodation is an important consideration while you are living away from home. We have staff housing on the Temasek Polytechnic campus, but we do not have a student hostel for international students here in TP. Therefore, in this project, your task is to design an ECO-HOSTEL.

OFFICE BUILDING

The skills include drafting, performance analysis for design development and energy simulations. With lab-sheets addressing the same building context, students tend to relate, analyse, and evaluate the connections while focussing on skill development.

Figure 2: Implementation of integration framework

Table 3: Survey questions

ATTITUDE	Q1	Integration provides a wider perspective increasing my interest and open-mindedness to the building industry.
	Q2	Having a similar design context has helps in to develop confidence and working efficiency
KNOWLEDGE	Q3	Working on the same context helps in a holistic understanding of the design process followed by the industry
	Q4	Integration gives opportunities for critical thinking skills as I had to consider various concepts across modules
SKILLS	Q5	Working on the same context allows to focus on various software, their specific capabilities and relevant application
	Q6	Integration required reviewing the model a few times which helps me sharpen my modelling and simulation skills (or) Integration of lab-context helps my learning speed and thus exploration of the given tool beyond lab-work

The 2021 intake, from semester 4 (year 2) provided the sample for module integration using coursework and the 2022 intake, from semester 3 (year 2) for module integration using project scenario. A random-sample of 40 - 45 students each cohort participated in the survey (approximately 60% of the intake) . The survey consisted of six-questions (Table 3) over a 7-likert scale conducted using Microsoft Forms. Though the survey responses were from cohorts, the overall profile of the intntake quality were similar. Informal interviews were conducted with a random 10 students for each scenario to clarify and probe into open-ended feedback from the survey questionnaire. This helped increase the validity of the quantitative strand.

Results and discussion

Module integration through project scenarios: The survey outcome tends towards '*Agreeable*' with an average above 5 as captured in Figure 3. It is evident that there is a correlation between the learning integration and impact on knowledge, skills, and attitude, with highest impact on skills, closely followed by knowledge and then attitude.

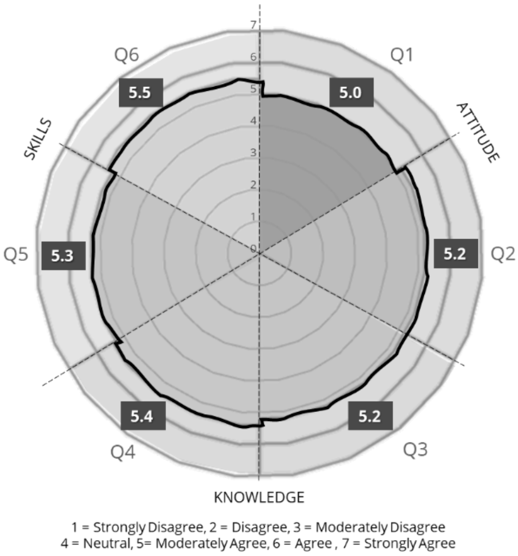


Figure 3: Survey outcome on module integration using project scenario

The design process for a sustainable building involves multiple iterations to building design at its inception during the concept phase. Since the project adopted a similar implementation process, students required to re-construct their models while revisiting green-building concepts along with feedback at regular intervals. This additional practice may have contributed towards the tilt on skills acquisition in an integrated project scenario. Most students shared the following when probed during open-ended interviews:

- Appreciation of the interconnectivity towards gaining a broader picture of the module-level learning within the vast building industry.
- Ability to visualize usefulness of the learning content in their future workplace (Meaningfulness)
- Deep learning as they do not need to shuffle thinking different context amongst modules. This also led to overall time-management.

Students also shared few challenges:

- Limitations to the ability or depth of learning from one module project impact the other module and thus their overall grade and performance, especially in a vertical integration scenario.
- Comprehension of the integrated work-process along with new learning.
- Compromise in project consultations for groupmates placed in different classes for the modules involving integration.

Module integration in coursework (practical labs): The survey outcome of integrated coursework is presented in Figure 4. It is observed that the overall average is slightly higher than integration using project scenario. The impact on knowledge (critical thinking) was also higher followed by a clear demarcation to skills acquisition followed by attitude. The ability to better comprehend knowledge when presented in teaching materials is evident, in comparison to self-directed integration within project-scenarios.

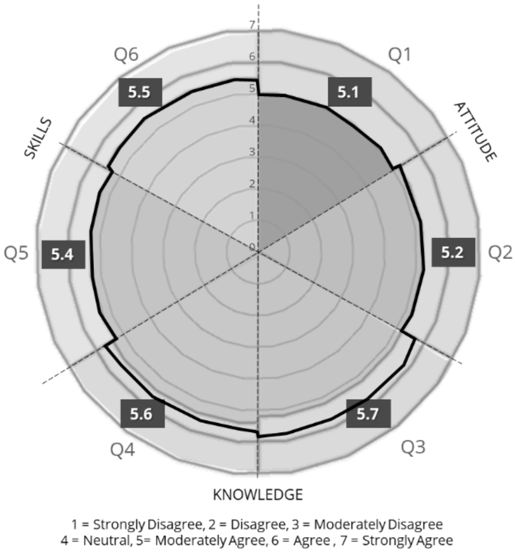


Figure 4: Survey outcome on module integration in coursework (practical labs)

During the open-ended interviews, many students re-confirmed the following:

- Ease of software comprehension as the course material integrated subject of study amongst the core-modules, allowing them to focus on the skills and further application.
- Possibility of sharing of data, drawings, 3D-models, or information across modules resulting in the ease of learning-transfer to integrated projects, if need be.
- Visualize the same subject (building scenario) from various perspectives providing an in-depth understanding which otherwise is quite challenging.

It has been observed that most students recorded that there were no challenges, and the integration made learning easier and convenient thus enabling them to establish connections beyond a specific module. Few struggles recorded by students were:

- Confusion in the use different software, keyboard, and mouse triggers, particularly when integration of lab-sheets happened during the same semester.
- In case of absence, since the lab-sheets involved the development of the 'same' building and not independent of each other, the catch-up with learning for the forthcoming lesson involved additional effort.

It was also acknowledged that the conscious integration of subject materials from the lecturers motivated students towards to voluntarily think across modules while working on self-directed assignments and projects.

Conclusions

The basis for a major curriculum integration though project and coursework materials was explored in this paper. The integration intended to construct learning connections across modules in order to replicate the real-world green-building industry. Based on the result of the present study, it is observed that an integrated curriculum could significantly stimulate critical thinking, interest and skill-proficiency by promoting awareness, cohesion and re-emphasis of concepts across modules. The impact on critical thinking and skill-proficiency is comparatively notable, especially when driven by the teaching team and learning materials. It is simply a question of becoming familiar with this iterative cognitive process. Challenges of subject integration on student learning have also been identified but can be negated using addional time and resources by the lecturers considering the benefits of cognitive constructivism through this process.

Integration of other discipline-based modules is yet under development, particularly thouse pertaining to building services, and there are many plausible perspectives yet to be explored. The challenges of implementation, from the perspective of lecturers is another plausible area of study. This may account to additional time and motivation from the teaching faculty to ensure a convinced application of an integrated curriculum.

The population chosen for the survey though similar ni profile were from differnt cohorts. A continuous longitudenal study across the same cohort for both scenarios could provide a more comprehensive data, particularly when run through for atleast three consecutive cohorts. Differences in lecturer approach, subject delivery and project consultation may also contribute to the variations in survey response. A relative study using contriol and experimental groups would be an approach with higher validity. However, considering the limitation that it is essential that all graduates from the same cohort have similar experience, the approach could not be adopted.

Additional categorization and data analysis based on student background such as entry score to the diploma, current grade-point average for data analysis could reaveal further correlations in the findings. Further research comparing the survey outcomes and student scores in their respective modules would validate the extent to which critical thinking, interest and profiency have been gained at an individual level. This study could identify clashes in confidence and perception of integration against actual application and outcomes in assessments.

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THEORY TO PRACTICE: SYNERGISING CREATIVE AND CRITICAL THINKING TO GUIDE FINAL YEAR PROJECTS THROUGH THE RAINBOW FRAMEWORK - A STEM PERSPECTIVE

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Abstract

The fast changing, information driven economy demands the ability to synthesise diverse sources of knowledge to solve multifaceted real-world problems. Therefore, researchers have highlighted the need to inculcate creative and critical thinking skills and dispositions (CCTD) through intentional, and scalable educational efforts. To facilitate honing of CCTD in final year students about to enter the workforce, it is vital to equip lecturers in institutes of higher learning (IHLs) with necessary competencies and resources. The study distilled the theoretical understanding of CCTD to develop a framework (RAINBOW) of guiding questions to build CCTD. A qualitative research design was employed to understand the experiences of lecturers and students in final year projects (FYP) and seek feedback on proposed framework and interventions. Focus group discussions (FGDs) were conducted with lecturers and final year students from multiple disciplines including Engineering, Infocomm Technology, Health, Hospitality, and Management. Findings revealed challenges faced in FYP, the skills and dispositions required to do well, indicating a clear need for suggested interventions. Key FYP challenges articulated by students included not knowing where to start or what questions to ask, finding the appropriate resources, and adapting to unexpected problems. Salient FYP challenges faced by lecturers included meeting project expectations, guiding students on how to get started and go through the process leading to the final presentation. Both students and lecturers indicated thinking critically, communicating well, and developing creative solutions as top 3 skills required to do well in FYP, while resilience, ownership, and openness were listed as the top three dispositions. They reiterated the need for guidance and resources to help them prepare better for FYP. These needs were mapped with CCT processes to refine RAINBOW framework of guiding questions to help them recognise real issues, ask the right questions, interlink the information, envision the solutions, balance the implications, observe the changes, and widen the possibilities, through project work. Interventions recommended include RAINBOW based e-course and Communities of Practice (CoP) for staff, complemented with parallel e-course and sharing of past projects for students. The paper also covers limitations and implications for future research.

Keywords: *Critical and Creative Thinking Skills, RAINBOW Framework, Final Year Projects, STEM*

Introduction

21st century workplaces are in a state of continuous innovation and in need of engineers with creative and critical thinking skills necessary to solve present and future challenges (Tucker, 2001; Twohill, 2012). These critical core skills are essential to manage challenging workplace projects, to unpack issues and to create novel and well-balanced solutions. Peterson et al. (1997) showed critical thinking as the most important element in medium to high complexity jobs which are defined as encompassing a wide array of tasks including decision-making, planning, negotiation as well as engineering, and problem-solving.

This challenging workspace regime places a demand on educational institutions to produce a workforce of independent thinkers, problem solvers, and decision makers (Silva, 2009). According to Soule and Warrick (2015), the 4Cs (critical thinking, communication, collaboration, and creativity) are the main skills that would complement core academic subject knowledge. The business need for innovation shows the importance of teaching undergraduate engineering students how to be better creative and critical thinkers. Unfortunately, the literature in this area suggests critical thinking stagnation and creative decline in undergraduate engineering students (Sola et al., 2017).

Evidence shows that teacher competencies, teaching instructions, and the learning environment directly influence students' creativity and higher-order reasoning (e.g., Ames & Archer, 1988;

McKeachie, 1986; Ng & Smith, 2004; Nolen, 1988; Smith, 1977; Tan, 2004). Consequently, appropriate design and intentional integration of teacher competencies, teaching instructions, and the learning environment can foster students to be more creative problem solvers. To fulfil the mandate of guiding students effectively to think creatively and critically, the lecturers must be prepared first. They need to be skilled and familiar with the processes and knowledge of creative thinking, problem-solving and experiential methods, and the ability to use research to guide classroom practices (Houtz, 1992). To fill this gap, a seven-step framework of guiding questions was conceptualised, and corresponding curriculum interventions were proposed for the professional development of lecturers to prepare them to supervise students' project work. Student development interventions were also suggested in parallel to prepare them for project work.

Methods

Qualitative research was employed to gather insights and seek feedback from key stakeholders. Two FGDs were conducted with experienced and novice lecturers from various disciplines (N=6 each). And 1 FGD was conducted with final year students (N=8) from various disciplines and levels of performance in FYPs, to understand their experiences and seek feedback on the conceptual framework and potential interventions. Qualitative data collected on experiences such as challenges and rewards, attitudes and skills, gaps and interventions was subjected to thematic coding. The findings were subsequently analysed to refine the conceptual framework of RAINBOW and recommend corresponding interventions.

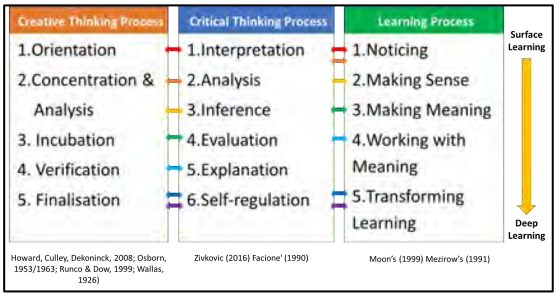
Literature Review and Conceptual Development

Creative Thinking: It is the capacity to generate a variety of ideas, use ideas in unusual ways, and perceive patterns that are not obvious, to produce novel possibilities that have the potential to address an intention or objective (Ramalingam et al., 2020).

The creative thinking process comprises of several stages as described by various researchers (e.g., Howard et al., 2008; Osborn, 1963; Runco & Dow, 1999; Wallas, 1926). For this study, it has been identified as a five-stage activity: (1) The orientation stage is where the individual identifies the problem that must be solved (Osborn, 1963). Some activities include problem selection (Busse & Mansfield, 1980), problem finding (Runco & Dow, 1999), problem differentiation (Bruford, 2015), posing the problem and constructing a problem (Mumford et al., 1994). (2) The concentration and analysis stage is where the individual focuses their attention on information or solutions deemed to be adequate and rejects the other solutions (Botella et al., 2011; Carson, 1999). (3) Accordingly, incubation occurs (Botella et al., 2011; Osborn, 1963; Runco & Dow, 1999) and is the time of solitude and relaxation where ideas association occur at a subconscious level (Carson, 1999). Ideation, with the generation of further ideas which are not necessarily judged nor assessed, surfaces as the main activity in this stage. The individual also experiences an illumination i.e., the emergence of an idea, or solution (Carson, 1999; Shaw, 1989; Wallas, 1926). (4) For the verification stage (Wallas, 1926), new ideas are tested and verified, leading to the elaboration of a solution and its production (Carson, 1999). Synthesis is evident in this stage, which consists of gathering ideas together and distinguishing relations between them. This work corresponds to developing and implementing ideas through a search for solutions (evaluation, selection, and redefinition) and then accepting this solution (promoting an idea, looking for its strengths and drawbacks). (5) The finalisation stage concludes refinement and adjustments (Botella et al., 2011; Cropley & Cropley, 2012). The individual reflects and reassesses production and may choose to finish, elaborate, abandon, delay, store, or destroy it.

Critical Thinking: It can be described as the metacognitive ability to ask critical questions, test assumptions, review evidence, consider new perspectives and explore decision-making alternatives (Miller et al., 2014). Good critical thinking can also be understood as a process of reflecting rationally and critically on one's assumptions and beliefs (Mezirow, 1991). In a nutshell, an ideal critical thinker possesses both analytical skills and appropriate dispositions (Gul et al., 2010; Perkins et al., 1993). Most of the literature focuses on the critical thinking skills and dispositions (e.g., Dewey, 1993; Ennis, 1985, 1996; Facione et al., 1994; Facione, 1990; Fisher & Scriven, 1997; Paul & Elder, 2006). Zivkovic (2016) advanced Facione' (1990) model to propose a possible six-step process: (1) The start of this process is signalled by the evidence of an ill-structured problem. The interpretation step requires identifying the problem and then defining what influenced this to occur. The formulation of the question in context, categorisation, decoding significance and clarifying meaning is vital at this stage. (2) The analysis step is to investigate the assumptions, examine ideas, opinions and arguments involved in the situation or problem. (3) Once the research is conducted, the inference step will take place to evaluate the information factually. The activities involved include recognising predispositions and weighing the information from all resources to reach a realistic and practical conclusion. One should also query evidence, conjecture alternatives, and conclude this step. (4) The evaluation step is to establish the significance of the conclusion and includes assessing claims and arguments, considering all points of view, and being open-minded, which is a good time to involve others in finding the best solution. (5) The explanation step involves communicating the findings and results, justifying the procedures, and presenting arguments. Failing to do so can cause much confusion. (6) The final step, self-regulation, suggests the need to reflect, question, confirm, validate, and connect the proposed solution to ensure a complete process and conclusion.

Synergising Creative and Critical Thinking to Transform Learning: To transform thinking process, we must attempt to change a persons' thinking habits and patterns through noticing, making sense, finding meaning of the new idea, reflecting on their presuppositions resulting in a change of their thinking pattern (Mezirow, 1991). Figure 1 illustrates through colour-coded arrows how creative and critical thinking processes run parallel and could be mapped to the learning process to enhance learning. While creative thinking strengthens ideation, critical thinking provides reasoning, together they transform learning.



Creative Thinking Process	Critical Thinking Process	Learning Process
1.Orientation	1.Interpretation	1.Noticing
2.Concentration & Analysis	2.Analysis	2.Making Sense
	3.Inference	3.Making Meaning
3. Incubation	4.Evaluation	4.Working with Meaning
4. Verification	5.Explanation	
5. Finalisation	6.Self-regulation	5.Transforming Learning
Howard, Culley, Dekoninck, 2008; Osborn, 1953/1963; Runco & Dow, 1999; Wallas, 1926)	Zivkovic (2016) Facione' (1990)	Moon's (1999) Mezirow's (1991)

Figure 1. Synergising Creative and Critical Thinking to Transform Learning

To enable students think creatively and critically and move beyond surface learning in FYP, a 7-step framework of guiding questions was developed. As illustrated in Figure 2 below, each question aimed to inculcate certain CCT skills and dispositions, to help students deliver the FYP outputs in a more systematic way.

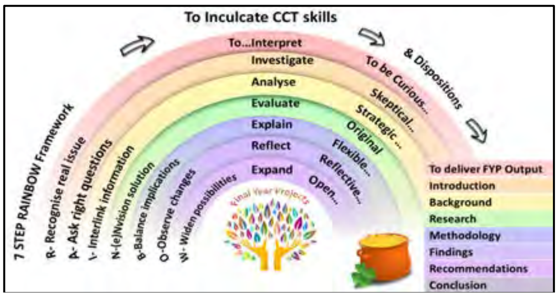


Figure 2. RAINBOW Framework

Results

The FGD findings have been organised under three categories: Challenges and Rewards seen; Attitudes and Skills needed; Gaps and Interventions identified. Both the FGDs with lecturers and students indicated the need for suitable interventions to help them inculcate CCTD through FYPs.

Challenges and Rewards: The biggest challenges cited by students in FYP included not knowing where to start, asking the right questions, finding the right resources, and adapting to curve balls, all of which require creative and critical thinking skills. A student shared during the FGD, *"We were lost, unsure of how, where to start, and what to ask"*. This anxiety mirrored in lecturers whose biggest challenge was meeting projects expectations by guiding students from beginning to the end. One of them shared the concern about *"How do we get started and guide students to learn, process data, and draw conclusions"*.

Students and lecturers also shared the perceived rewards from the FYP experience. While students cited gaining a sense of achievement and benefitting from the real-life experience, the lecturers appreciated the opportunity to help students grow and contribute to the industry through the FYP. A student stated *"(I feel) joyful to overcome challenge. (The FYP experience was) artistically fruitful"*, and a lecturer shared *"(It is) rewarding to go through the process to see students grow and create a product."*

Skills and Attitudes: During the FGDs, both students and lecturers indicated the need for skills to think critically, communicate well with various stakeholders and come out with creative solutions to meet client expectations. For example, students shared that *"We need to find our resources on how to make code better, through Googling & watching YouTube videos" and "Planning and infusing technology into the event itinerary was challenging. The challenge was what to include in the Virtual Reality with the aim of educating senior citizens. It challenged my creativity. I enjoyed it."* Lecturers reiterated that students should *"be critical in reviewing ideas", "know how to communicate with teammates", and "know how solutions can be designed".*

The discussions further highlighted resilience, ownership, and openness to be the top three dispositions required to do well in FYP. Students emphasised on the need to be resilient *"...keep bouncing back whenever you get knocked down ... "*; to take ownership *" "We are bound to face challenges, supervisor cannot spoon-feed us, need to* *do our own research"; and to be open to ideas, "Everybody has different ideas, (you) cannot just be set on you own idea, (but should) think about how the others' ideas will help."* Lecturers reaffirmed the need for *"Consistency"* and ownership as *"FYP is not a textbook. Students need to figure out the solutions… do research for insights…", "deep dive and ask questions…"*

Gaps and Interventions: Although students were taught a Critical Thinking and Problem-Solving module in year 1 but they may not recall the concepts sufficiently to apply them to project work in year 3. This is evident from the gaps highlighted by students during the FGD, including lack of preparedness, understanding, resources, ideas, and feedback. For instance, one of them shared, *"Searching for information on Google was frustrating at times" and "(I was the) only one giving ideas in the team."* Students requested guidance from their supervisors, specifically on how to ask and answer questions, overcome crisis, interpret, and ideate. Another student mentioned, *"ask us questions that the assessor may ask, to prepare us (for the assessment)" and "teach us how to interpret articles".*

The FGDs also showed that both lecturers and students were receptive to suggested interventions, including a RAINBOW based e-course and CoPs for lecturers and a parallel e-course with frequently asked questions (FAQs) and a sharing of past projects by seniors or through a discipline specific virtual gallery.

Discussion

The FGD revealed four key findings:

1) **Needs of Lecturers and Students** to adequately prepare them for FYP challenges. These needs could be shared with lecturers and students about to embark on this journey to prepare them mentally for the challenges ahead and ways to overcome them.

2) **Perceived Rewards of FYP** that make the experience worthwhile. These rewards could be highlighted to students and lecturers to generate their interest and commitment before they embark on their FYPs.

3) **Portfolio Development Opportunity** to build lecturers' capability in helping students develop CCTD in FYP. The potential application of the intervention could be shared with them to make them more receptive to their own development.

4) **Receptivity of Lecturers and Students** towards the interventions to develop creative and critical thinking in students. For example, online self-paced learning courses could be designed to take lecturers and students through the RAINBOW framework of guiding questions to develop CCTD. These could be supplemented with CoPs with lecturers sharing best practices or senior sharing tips with students.

Implication for practice

Table 1 illustrates how RAINBOW framework could be applied to a STEM project in Engineering.

Table 1. Application of RAINBOW to a STEM project in Engineering.

Applying RAINBOW Framework to a STEM Project ***enabling CCTD through guiding questions***
Recognise the real issue: • What are the clients' **needs**? *(E.g., People with intellectual disabilities need a wearable device which tracks location to inform guardian via a mobile application)*
Ask the right questions • What are the **Strengths/ Gaps of existing solutions**? *(E.g., Technology, Cost, Compatibility)* • What do we require **to fill gaps** and **fulfill client needs**? *(E.g., Parts - IoT module / Skills - Coding)* • What are the **constraints**? *(E.g., Budget/ Time?)* • How can I ascertain the **demand**? *(E.g., Survey/ Interview target Consumers)*
Interlink the information • How to create a **better device** by selecting the **right model/parts** and using **the skills**, within given **constraints,** to meet the **demand?** *(E.g., Firebase vs Amazon Web Services Database)*
N(e)nvision a solution • What are the most **critical features** to include? *(E.g., Location)* • Does the **solution address the gap**? *(E.g., Test location functionality)*
Balance the implications • How to **justify solution based on findings**? *(E.g., more expensive & reliable technology recommended as consumers are willing to pay higher price for accuracy)* • How **does new device fare on objectives** against existing devices? *(E.g., existing devices are cheaper but less accurate)* • How to **modify design** to improve outcome? *(E.g., implement Geocoding instead of Geofencing so that location boundaries can be defined by the device user instead of fixed in the code)*
Observe the changes • How did my **strengths/ limitations** affect the project? *(E.g., Strength- Coding helped in design)* • What have I learnt from the experience? *(E.g., understanding & meeting client needs)*

Widen the possibilities
- What could we do **better next time**? *(E.g., better time management)*
- How to **use learning in future** (other module/ project/ future job)? *(E.g., project management)*

RAINBOW framework is a systematic approach to prepare the lecturers and students to recognise the real issue, ask the right questions, interlink the information, envision a solution, balance the implications, observe the changes, and widen the possibilities through project work. It focuses on building specific abilities and lasting dispositions which would be valued in the industry. Similar to the project shown in Table 1, this framework of guiding questions could be applied to various projects across STEM or Non-STEM disciplines to develop CCTD in students.

Conclusion

This study has contributed to our knowledge on the challenges faced by lecturers in supervising final year projects in an IHL and how they can be supported in developing critical and creative thinking in students, specifically during the process of supervising students' FYPs. The anticipated outcome of this is the more deliberate integration of the RAINBOW framework into a professional development programme for lecturers and resources for students.

For STEM students, many of whom would likely join the workforce after completing their FYPs in their Final Year of study, this process could help build confidence in their ability to solve real-world problems innovatively and justify them with concrete rationale, thereby contributing to the scientific community.

The limitations of small sample size in qualitative research apply. The next step would be to translate the RAINBOW framework into e-courses and CoPs, as recommended by the findings. Future studies could be done to assess the effectiveness of the intervention in building CCTD with the IHL students or do comparisons across domains, where relevant.

Acknowledgements

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A PRELIMINARY STUDY ON THE EFFECTIVENESS OF ACTIVE-COLLABORATIVE LEARNING IN PRAGMATIC-BASED MECHANICAL ENGINEERING MODULE

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Abstract

This paper studies the effectiveness of Active-Collaborative Learning (ACL) in a pragmatic-based engineering module offered by the School of Mechanical and Aeronautical Engineering (MAE) in Singapore Polytechnic (SP). Being pragmatic is one of the essential components of Computer Aided Machining (CAM), a skillset that was addressed in one of the advanced modules in the second year of SP MAE studies. In essence, developing mastery in CAM requires students to attain the highest competency in the Bloom Taxonomy within the 15 weeks of study, which was often challenging for students. There have been few studies about the pedagogy in pragmatic-based modules as of this writing, which prompted the author to conduct research to develop a more comprehensive instruction method and find common ground with lecturers who teach modules of a similar nature. The implementation of ACL provided a two-way learning approach in the classroom setting, allowing for greater interactivity and knowledge exchange among students and lecturers. The two primary activities that facilitated ACL implementation were the pre-class preparation and the in-class activity. The pre-class preparation entails students to first complete the assigned tasks before attending the subsequent lesson. Knowledge-exchange-based activities were then incorporated into the in-class activity, making it more participatory and, as a result, attaining the ACL objectives. Quiz components of a total number of 208 entries were considered to determine the effectiveness of this approach. The findings indicated that ACL was effective as the quiz results revealed a positive correlation between the students went through ACL setup and the quiz scores. The statistical evidence that ACL was effective was supported by the fact that students who participated in ACL had higher mean of quiz scores than those in control group, along with a high t-value and low Cohen's ds value. Following the conclusion of the learning of one major skill, a student perception survey was included. The survey's feedback scores showed that students were getting better at understanding and applying their acquired knowledge of CAM. In conclusion, the higher degree of interactivity and knowledge exchange in ACL has produced a productive learning environment where the students are better able to comprehend and integrate the concept and subsequently complete the assignments.

Keywords: *Pragmatic-based Module, Computer Aided Machining (CAM), Active Learning, Active-Collaborative Learning, Pragmatic*

Introduction

"To teach is to engage students in learning" (Christensen et al., 1991). That's the essence of Active Learning pedagogy. Active learning differs from typical lecture-based teaching approaches in that it prioritizes student engagement, interaction, and collaboration. Bonwell and Eison (1991) discovered that after the active learning technique was imposed on their learning, the pattern of communication among the students in the class had significantly improved. As active learning promotes inclusivity and diversity in the classroom, learner-centred activities are becoming increasingly important, and it should be designed with the intention of enhancing the higher order cognitive skills among students in the Revised Bloom's Taxonomy (RBT) pyramid (Anderson and Krathwohl, 2001; Bergmann and Sams, 2012).

In a typical active learning environment, students were grouped together so they could share ideas and learn from their peers instead than depending solely on lecturers to impart knowledge. (Ballen et al., 2017; Cho et al., 2021; Mason et al., 2013). This is the Collaborative Learning, one of the commonly used strategies in active learning. Collaborative learning is a joint learning between the students and teachers, where the efforts can come primarily from students, or the partnership between students and teachers (Smith et al., 1992). The introducing of this interdependency during classroom learning has increased the cognitive learning among students, which has created a positive hype in terms of intrinsic motivation to allow students to learn better (Järvenoja et al, 2020; Scager et al., 2016). The proliferation of peer teaching, especially in a tertiary education institution, accelerates the collaborative element among peers, provides students the necessary platform and motivations to lead the discussions in the classroom settings.

Studies have proved that by adopting the pedagogical revolution of active learning method in Science, Technology, Engineering and Mathematics (STEM) modules, students are able to master the subject well (Freeman et al., 2014), thereby closing the achievement gap between a below-average and above-average STEM student at the expense of supplementary classes (Theobald et al., 2020). This has motivated the author, together with only a few studies about the pedagogy in pragmatic-based modules as of this writing, to explore the possibility of adopting this pedagogy into the pragmatic-based Computer Aided Machining (CAM), a skillset that was addressed in one of the advanced modules in the second year of Singapore Polytechnic (SP) School of Mechanical and Aeronautical Engineering (MAE) studies.

Pragmatic-based lesson often drawn from a scientific or a technical discipline, emphasizing on philosophical or practical approach that highlights the practical consequences and usefulness of ideas or actions of real-world problem solving. Given the nature of pragmatic-based lessons, where students are required to put their plans into action at the conclusion of their studies, the learning curve is steep if they have little background information or expertise. This is apparent in the field of CAM, where students are required to fabricate the part at the end of their studies rather than just comprehend the theory.

CAM, one of the leading technologies deployed in Precision Engineering industries, is defined as a use of software to introduce toolpaths to control a Computer Numerical Control (CNC) machine to automatically perform the subtractive machining operations and thus, enable the end user to have a highly precise and accurate part. Understanding the basic principle of machining is thus crucial for assuring the production of extremely precise parts while maintaining their safety and effectiveness in terms of cost and time. When programming in CAM, learners must be able to envision the cutter movement during the actual cutting process as well as the shape of the materials after each cutting operation, which may be difficult if they are unfamiliar to this technology. As shown in Figure 1 below, developing mastery in CAM requires students to attain the highest competency in the Bloom Taxonomy within the 15 weeks of study, which raises the bar for learners to master this skillset both conceptually and practically.

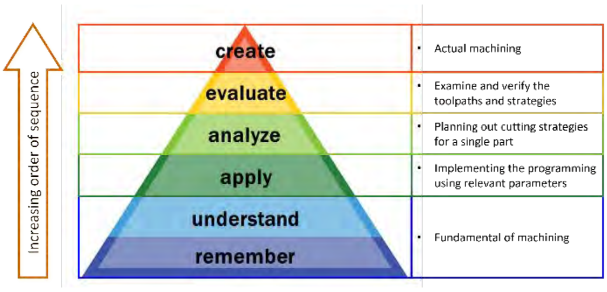


Figure 1: Detailed CAM process distribution based on Revised Bloom's Taxonomy, remodeled with model from Vanderbilt University Center for Teaching under Common Creative Attribution license

This paper researched on active-collaborative learning (ACL) in CAM module. The groups involved in this study were the SP Year 2 Diploma in Mechanical Engineering (DME) students. A study was carried out to differentiate the outcome of quizzes results between the two groups, with surveys and questionnaires conducted after the completion of learning of a major skillset. Two area of concerns were addressed in this paper:

(a) The ACL improved students' performances in terms of assessments scores.

(b) The ACL was able to engage and motivate students to learn better prior and during class.

Methodology

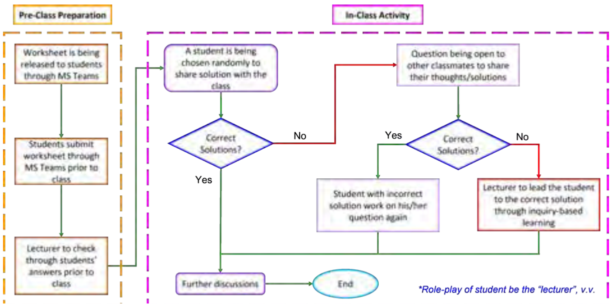


Figure 2: ACL Concept Flowchart

Figure 2 illustrates the concept flowchart of the active-collaborative method that the author has deployed in this study. Two primary activities were deployed to facilitate this implementation: the pre-class preparation and in-class activity. Microsoft (MS) Teams was the main communication platform for all assignment submissions.

The objectives for pre-class preparation were:

- To enable students to summarize the lecture contents after reviewing.
- To enable students to apply the fundamentals that they have learnt to perform toolpath programming operations.

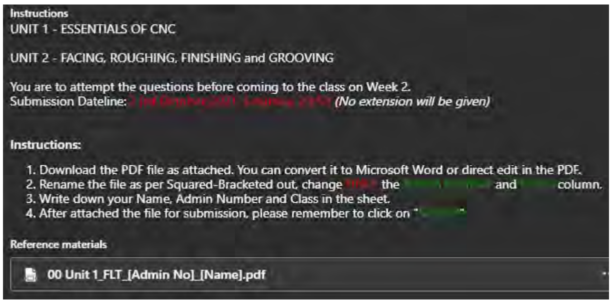
The objectives for in-class activity were:

- To enable students to explain and justify their solutions, prompting a recall process of what they have learnt.
- To enable students to cross-refer their solutions with their peer, reflecting about where were the similarities and differences between the solutions.
- To enable students to respond to their peers' queries, allowing them to have a better peer-to-peer learning.
- To allow lecturer to gauge the student's level of understanding with a role-swapping activity.

Pre-class preparation:

Students were told on the objectives of the activities during the first class so that they were more appreciative of the activities and therefore boost their involvement and commitment to both the pre-class and in-class activities (Deslauriers et al., 2019; Owens et al., 2020; Prince et al., 2006). In order to show an unbiased selection process for presenters, students were informed of the procedure and ground rules.

Worksheet was distributed through MS Teams in advance and students were required to submit their solution through MS Teams prior to the class.



Instructions
UNIT 1 - ESSENTIALS OF CNC

UNIT 2 - FACING, ROUGHING, FINISHING and GROOVING

You are to attempt the questions before coming to the class on Week 2.
Submission Dateline: [redacted] *(No extension will be given)*

Instructions:

1. Download the PDF file as attached. You can convert it to Microsoft Word or direct edit in the PDF.
2. Rename the file as per Squared-Bracketed out, change [redacted] the [redacted] and [redacted] column.
3. Write down your Name, Admin Number and Class in the sheet.
4. After attached the file for submission, please remember to click on "[redacted]"

Reference materials

00 Unit 1_FLT_[Admin No]_[Name].pdf

Figure 3: Screenshot of instructions using Microsoft Teams

To return (20)   Returned (0)

☐	Name	Status
☐	AP [redacted]	✓ Handed in
☐	[redacted]	✓ Handed in
☐	GK [redacted]	✓ Handed in

Figure 4: Sample of Students submission from Lecturer point-of-view

ME2011 COMPUTER AIDED MACHINING

[redacted]

Student work
✓ Handed in View history

Unit 5_FLT_[2029711]_[Ch.. ···

Take action in student view

Feedback

Enter feedback

Figure 5: Example of student's work, from Lecturer POV in MS Teams

Questions in the worksheet should be designed in a way that students were able to recall *(lower order cognitive skill),* analyse and apply *(higher order cognitive skills)* about what they had learnt in theory.

4. A Production Engineer has come out a drawing as per below. As a CAM Engineer, you are to decide the machining strategies to complete the part. List down all your strategies and explain the rationale for your choice.

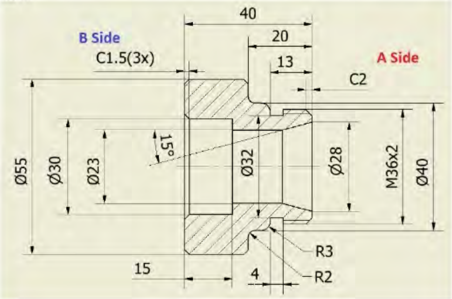


Figure 6: Example of Higher Order Thinking Skills question

In-class activity

The collaborative element was introduced to involve the student-to-student learning and teacher-to-student sharing. Students were the focus of the class, leading the teaching session by describing the "what" and "how" to the posed question. In this design, the lecturer played more of a facilitator role, supplementing the presenter's missing points and directing the presenter to the appropriate solution through a series of scaffold questions if the solution offered was incorrect.

Students were often chosen at random by Wheel of Fortune to play the "lecturer" role, in which he or she would share lead the class discussion, regardless of the accuracy of his or her solutions. Nonetheless, students were strongly encouraged to volunteer to share their solutions with their peers so that they may learn from one another. Quoting from Bergmann *"…But when learning is in the hands of the students and not in the hands of the teacher, real learning occurs."* (Bergmann and Sams, 2012, pg. 111). Following the sharing, the selected presenter will be given some time to address any questions raised by classmates. It is worth noting that the lecturer has the option of role-playing as a student during the classroom activities setup and posting some questions that the lecturer believes necessary or capable of improving the student's understanding. Through this role-swapping activity, the lecturer would be able to provide timely feedback since he/she gained a better insight of the degree of understanding among students, thus, directing them to the correct solutions through inquiry-based learning.

Results and Discussion

Quiz results analysis

A total of 208 entries *(N=208)* were recorded, where two main groups consisted of control group *(n=103)* and experimental group *(n=105).* To access the effectiveness of new approach, only the quizzes scores were used for the analysis in this study. Surveys feedback and questionnaires scores were being recorded after the completion of learning of a major skill. The primary objective of included surveys was to observe and reflect on how students coped with their studies with active-collaborative learning (ACL) in class together with the quiz results.

Hypothesis of this research was defined as: *ACL is able to improve student's assessment score for pragmatic-based module.*

Homogeneity of variances was deployed to check the dependent variables before analysis. Confirming with F=1.38 *(p=0.05),* the null hypothesis stands, meaning that the variances between two samples of students are the same.

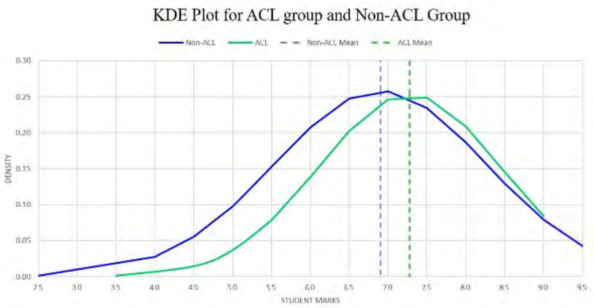


Figure 7: KDE Plot for the ACL group and non-ACL group

Kernel Density Estimation (KDE) graph with a bandwidth, h=2% was plotted. It showed that the ACL group achieved a higher mean *(72.0)* compared to the non-ACL group *(69.0)*. Independent sample t-Test *(95% confidence interval)* was carried out to further justify the results.

Table 1: Independent sample t-Test results between Experimental Group and Control Group

Group	Experimental	Control
N	103	105
Mean	72.8	69
SD	11.6083	13.661
t	2.132*	
Cohen's ds	0.3	

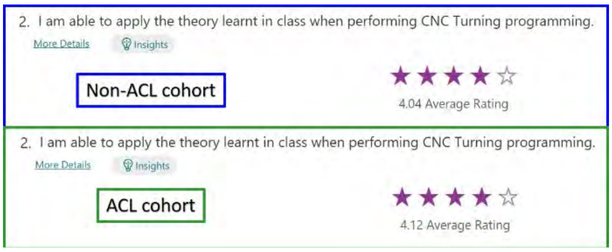
*$p<0.05$

The standard deviation for experimental group *(mean=72.8)* was 11.6083 while for control group was 13.6610. Null hypothesis of the two group had no statistical difference was thus rejected *(p<0.05)*. A t-value of 2.132 *(p<0.05)* suggested that observation between two group was statistically significance, which further proved that ACL was indeed having an impact on the students' studies. Cohen's ds value was being calculated as 0.3, indicating that there was a small positive significant difference *(small effect size)* between the two groups (Cohen, 1988). The hypothesis for this research was then valid. Experimental group outperformed the control group, albeit with a small effect size d=0.3 *(p<0.05)*.

Based on the results obtained above, the hypothesis was accepted, ACL improved the students' assessment score, albeit with a small effect size.

Surveys feedback

A student perception survey was conducted to investigate the relationship between how well students learned in ACL and their ability to apply the corresponding skills. Survey questions were designed to assess students' abilities to integrate lower and higher order thinking skills. in terms of Understanding, Applying and Analysing. Figure 8 and 9 showed the differences in score for control and experimental group in terms of feedback score for two major skills: CNC Turning and CNC Milling.



2. I am able to apply the theory learnt in class when performing CNC Turning programming.

Non-ACL cohort

★★★★☆

4.04 Average Rating

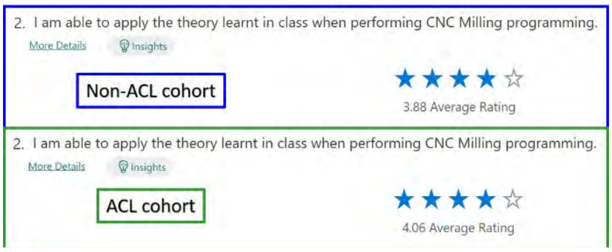
2. I am able to apply the theory learnt in class when performing CNC Turning programming.

ACL cohort

★★★★☆

4.12 Average Rating

Figure 8: Survey score for CNC Turning



2. I am able to apply the theory learnt in class when performing CNC Milling programming.

Non-ACL cohort

★★★★☆

3.88 Average Rating

2. I am able to apply the theory learnt in class when performing CNC Milling programming.

ACL cohort

★★★★☆

4.06 Average Rating

Figure 9: Survey score for CNC Milling

The feedback score indicated that students who participated in the ACL setting learnt more effectively. Increases in rating for both CNC Turning (from 4.04 to 4.12) and CNC Milling (from 3.88 to 4.06) indicated that students were able to recall the fundamentals of machining and apply them when planning cutting strategies. In accordance with the quiz results of the two groups of students, it was discovered that students who had participated in ACL activities were more capable of grasping the theory of CAM than those who had not. It further demonstrated how ACL was able to enhance the CAM learning environment for students.

Questionnaire feedback

A second student perception survey was also conducted to allow students to rate their ACL experience. To further understand the students' reactions and satisfaction with ACL, eight questions were conceived and produced.

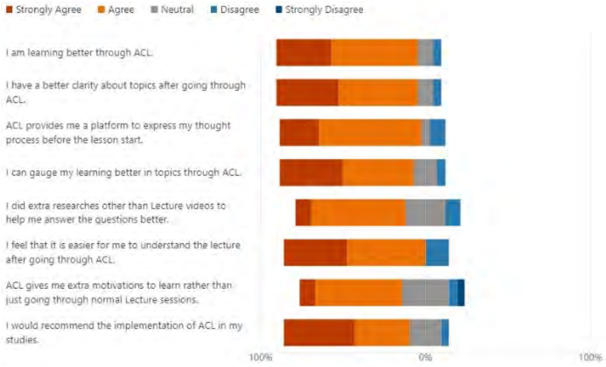


Figure 10: ACL Questionnaire results

Table 2 showed some of the constructive feedbacks given by students regarding their learning in the active-collaborative learning (ACL) approach.

Table 2: Feedback from students about implementing ACL in classroom setup

> *"The ACL worksheet allows me to practice and implement the knowledge i've learned from the various topics. I feel that since its not graded doing it is more for your own benefit and i don't have to worry about getting the correct answers but instead more of getting the correct idea or understanding. Since we go through the tutorials in class also instead of just submitting for grading without going through i'm able to clarify any doubts I have on any questions to help further my understandings. Overall i think the ACL is beneficial in helping my learning and understanding of the various topics."*

> *"It gave us an opportunity to learn at our own pace which makes us learn better. We are also able to do additional research online if we do not understand any things rather than being blur blur in class."*

> *"It can be time consuming sometimes but it allows me to be more prepared for the next lesson. It is also one of the few times I actually learn something when at home."*

> *"i found it very helpful as i usually do not really pay too much attention to the online lectures but the ACL requires me to really look into it more rather than just briefly looking through it. also it points out questions i don't understand where we can ask and clarify our questions."*

> *"Given the circumstances, ACL is definitely a viable solution. Making us submit PDF through msteams definitely has helped me understand the theory aspect a lot more. Going through the tutorial as a class the following monday is also a very good structure of this mastercam module, definitely has cleared alot of doubts that we have in mind. It has helped us with the quizzes a whole lot. Thanks Mr Henry"*

> *"It was well implemented. However, it was through the lecture where we had to present, where i actually found interest to learn more. Overall, i found it to be a good approach still as it motivates me to be more self directed."*

> *"The active worksheet has allowed me to think more about the topic(s) and ensure that I do work instead of procrastinate which does considerable help when Mill/Turning Quiz as it gives us some examples/practise on topics …… Only downside is the increased weekly work load now we must watch video, do coursework, do Lab assessment and complete tutorial which I suppose say it's fair enough given Computer aided machine is 6 credit module……"*

While some students thought that ACL was adding extra loads to their already hectic schedule, the majority of them nevertheless expressed positive comments. Students, in particular, stated that ACL increased their intrinsic motivation, allowing them to be more self-directed and eager to go the extra mile by conducting their own research. This was reflected by the feedback scores for questions 5 and 7, which were designed to establish whether ACL was able to enhance motivations among students and so promote self-directed learning among students.

Conclusions

Learners in 21st century shouldn't be taught using the pedagogy of 20th century (Suárez et al., 2021). Indeed, due to the rapid evolution of the internet, knowledge is now available at the touch of a button. In light of this, pedagogies should evolve to meet the contemporary profile of students, who are more technologically savvy.

In this pilot study, Active-Collaborative Learning (ACL) went under trial on SP DME Year 2 students who were taking CAM module. It leveraged from the current Flipped Learning setup to introduce an active and collaborative learning session during in-class activity. The hypothesis of this study was defined as ACL is able to improve student's assessment score for pragmatic-based module. Based on the analysis of recorded quiz results, ACL group was performing better than the non-ACL group, where it saw an increasing of mean from 69.0 to 72.8. The result was statistically significant, albeit with a small effect size of 0.3 *($p<0.05$)*. Students were able to apply their theory knowledge more effectively when programming the cutting path, as evidenced by an increase in positive replies on the post-learning survey. An increasing score from 4.04 to 4.12 for CNC Turning and 3.88 to 4.06 for CNC Milling were recorded, showing that the students were learning better in ACL setup. Questionnaires feedbacks were largely positive among students implementing ACL in their studies. This study received a surprising response from students, as intrinsic motivation enhanced and encouraged them to be more self-directed, resulting in better learning than the traditional approach.

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ENHANCING PROFESSIONAL IDENTITY FORMATION VIA INTERNSHIP USING CDIO FRAMEWORK

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Abstract

Internship had always been considered a means for students to develop their professional identify. This paper shares the outcomes of a study aimed at determining a sense of professional identity among students from the Diploma in Chemical Engineering (DCHE) after they completed their internship. This is especially important as recent studies on the impact of Covid-19 pandemic has shown potentially negative influences on professional identity formation, as many students were largely confined to working from home. This paper first provides a literature review of how internship can enhance professional identity development. It then presents the DCHE spiral curriculum that strives to prepare students for the chemical process industries where professional identity is assumed to develop naturally as students went through their studies in campus. This is followed by a discussion of a survey findings (number of responses, n = 53) aimed at finding out the students' impression of how well the DCHE course had prepared them for the development of their sense of professional identity as a chemical engineering technologist. These students had spent a good part of their internship working from home during the pandemic. This survey follows from an earlier focus group discussion that the author was involved in with a small group of 22 DCHE students who informed of the disorientation they faced and anxiety during their internship; over what they can learn when they were kept away from the workplace due to Covid-19. The survey findings indicated that while a good number of students reported on still having positive experiences, their feedback also indicate that more needs to be done. This paper concludes with ways in which the CDIO Framework can be used to leverage on other modules in the DCHE curriculum to enhance students' professional identity formation during their studies in campus that support its continued development during internship.

Keywords: *Professional identity, chemical engineering, internship, CDIO Framework*

Introduction

In the simplest form, professional identity is the concept which describes how we perceives ourselves within our occupational context and how we communicate this to others (Neary, 2014). It is implicitly assumed that students will appreciate their professional identity through various learning tasks experienced over the duration of their study.

Rees & Monrouxe (2018) noted that professional identities are of utmost importance to any profession, as they are the cornerstone of professionalism, providing a professional with ethical frameworks within which he or she works. Possessing a strong professional identity can foster confidence in a practitioner, and others in that person. A lack of professional identity clarity has been found to have a significant impact on a profession's perceived value and on a practitioner's confidence in advocating for his/her professional opinions.

Among many disruptions brought about by the Covid-19 Pandemic, the one of interest in this paper is on the internship for students. Mustafa, Willems & Cheah (2022) reported on a focus group discussion they conducted for a small group of students from the Diploma in Chemcal Engineering (DCHE) of Singapore Polytechnic (SP). The findings indicated that students in general felt disoriented due to the lack of interactions with working professionals when working from home, and/or working on projects with reduced scope or more "desk-bound" such as documentation review.

Student Internship and Professional Identity

Holdsworth, et al (2009) considers internship as a form of "capstone experiences" or "capstone subjects" that are useful in assisting students in transitioning to the professional workforce. Internships constitute the earliest professional experience right after or while students pursue their professional qualifications. As interns, students go through a process of discovering and constructing their professional self, finding frequent contradictions and problems along the way (Karaja & Martinez Del Rio, 2018). It provides students not only the knowledge and skills usually developed in engineering programs, but attitudes and self-beliefs toward being able to practice as an engineer (Mann, et al, 2009). Indeed, Trede (2012) likewise suggested that internship is an ideal space to develop professional identity and professionalism in students, which include learning professional roles, understanding workplace cultures, professionalizing and socializing into a community of practice. Similarly, Dehing, et al (2013) reported that workplace learning has an overall positive effect on engineering students' development of clarity, i.e. they acquired a greater image of their professional future from such form of learning. Such "field experiences" (Hoffmann & Berg, 2014) gained provide the link students needed between classroom learning and actual workplace setting, and notion of professional identity thus develop from performing specific activities that are seen as core to the profession in question. This allows students to understand and adopt the attributes, beliefs, values, motives, and experiences of the profession. Recent works by Carvalho, et al (2021) also reaffirmed that work experiences played an important role in the meanings that students attributed to development of professional identify.

Internship for Chemical Engineering Students

Internship is a compulsory component for Year 3 DCHE students from SP. Its current form as a 22-week attachment (semester-long) to local companies is a direct response to the SkillsFuture Initiative; which in turn is the Singapore Government's national strategy to address the country's futrue developmental needs in Industry 4.0.

Internship is run on a "flip-flop" model, alongside the final year project; in which half of the cohort of 120 students will first complete the internship while the other half first complete the final year project. This is shown in Figure 1 for the DCHE course structure which follows a spiral curriculum. Prior to embraking on capstone project and internship, students go through 4 skills-based module in the first 2 years of study, one module per semester, as shown in Figure 1.

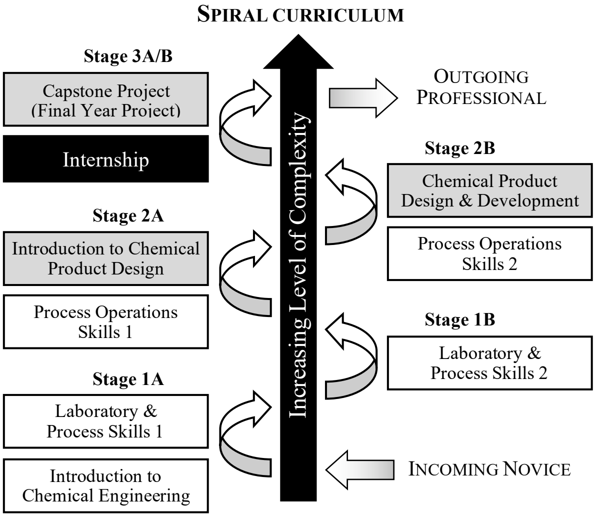

Figure 1. The DCHE Spiral Curriculum

The DCHE Curriculum and Professional Identity

When we started back in 2007 to redesign the DCHE curriculum using the CDIO Framework (www.cdio.org), we did not make an explicit effort to develop any sense of professional identity among our students. Even as we had over the years made many changes to the curriculum (e.g. Cheah, et al, 2013; Cheah & Yang, 2018), we had left the internship module untouched. We had at one time, replaced the internship with a structured training at the Chemical Process Technology Centre (CPTC) in Jurong Island. Suffice to say, we had left our students to figure out for themselves their career choices in the chemical processing industries, assuming this will eventually "come to them".

We started to pay attention to the question of professional identity when the SkillsFuture Initiative was introduced, as one of its key thrusts is to help Singaporeans made well-informed choices in education, training and careers (Cheah, 2016). One of the key focus in this area is the introduction of enhanced internship, which aimed to prvoide a more structured approach to training at sponsoring companies (Cheah & Yang, 2018). DCHE aligned its curriculum to the Skills Framework for Eneregy & Chemicals and introduced the 22-week internship in its present form. This also effectively replaced the training at CPTC which had ceased operation.

Findings of Survey Results on Student Internship Experience and Professional Identity Formation

A survey was administered to this cohort of students after their internship for the period September 14, 2020 to February 12, 2021. A total of 53 responses were collected, and some had to be discarded because they were either incomplete, or otherwise did not addressed the questions. The survey consists of 10 questions. Most of the questions are open-ended in nature, to allow students to pen down their answers in their own words. The first 2 questions (Q.1 and Q.2) tried to establish students' "baseline" understanding of their professional role:

Q.1 What does it mean to you, to become a "chemical engineer"?
Q.2 In your opinion, how is a chemical engineer different from other form of engineering, e.g. civil, mechanical, electrical, etc?

A majority of responses to Q.1 (33 students) focused on what chemical engineers do, which revolved around manufacturing activities to make useful products using a range of equipment and processes; and related work such as problem-solving and troubleshooting. A small number (13 students) mentioned having the right knowledge, skills and/or attitudes. For Q.2, which serves to discern if students see distinctions between being a chemical engineer compared other engineering disciplines, there are 47 useful responses that addressed the questions. There were 6 responses that were discarded, which covered only very generic areas. The useful responses are those that were able to pinpoint the processes involved, and a wider career options not limited to the chemical processing industries. These results showed that our students have a good understanding what the field of chemical engineering is about.

The next question (Q.3) attempts to capture students' notion of professional identity from their experiences in the first 2 years of study, where they completed 4 core skill-based modules, one in each semester (in Year 1 and in Year 2), using scenario-based learning as explained earlier (see Figure 1).

Q.3 Did you find the activities that you went through in the DCHE Laboratories (not including internship) gave you adequate understanding of the job functions of a chemical engineer? Did they help to shape your perception of the professional identity of a chemical engineer? If yes, explain with the help of examples what worked and why it worked. If no, explain why not.

Here 39 students who answered "yes" were able to cite module names and/or gave examples of activities they undertook, nearly all pertain to the 4 skills-based modules in the DCHE spiral curriculum. Although relevant, 5 responses were not included as students reported them as derived from their internship. These replies serve to validate that our laboratory activities indeed played a key part of helping to instill in students good understanding of the professional role of chemical engineers.

Next, in Q.4, we listed 9 statements, based on the Professional Identity Scale (Adams, et al, 2006) on how they felt about the profession using a 7-point Likert Scale from '1' (Strongly Disagree) to '7' (Strongly Agree) that is most representative of one's sentiment. We emphasized that there is no right or wrong answer. The 9 statements (S.1 to S.9) are shown below:

S.1 I feel like I am a member of this profession
S.2 I feel I have strong ties with members of this profession
S.3 I am often ashamed to admit that I am studying for this profession
S.4 I find myself making excuses for belonging to this profession
S.5 I try to hide that I am studying to be part of this profession
S.6 I am pleased to belong to this profession
S.7 I can identify positively with members of this profession
S.8 Being a member of this profession is important to me
S.9 I feel I share characteristics with other members of the profession.

Students' responses are shown in Figure 2. From the results it can be inferred that a large majority of students are probably still unsure of their identity as chemical engineers (S.1, S.2, S.6, S.7, S.8 and S.9). Many gave high scores of 'slightly agree' and 'neither agree nor disagree'; and most also do not express strong negative feelings of the professions (S.3, S.4 and S.5 with a large numbers who selected 'strongly disagree' and 'disagree'). Among the majority of students, there is a significant number of students who responded positively in terms of being pleased to belong to the profession (S.6), able to identify positively with members of the profession (S.7), and sharing the characteristics with members of the profession (S.9). Many also expressed that they felt like a member of the profession (S.1). However the affinity to the profession can still be further developed, as many may not have seen the importance to oneself by being member of the profession (S.8), or the ties to members of the profession (S.2).

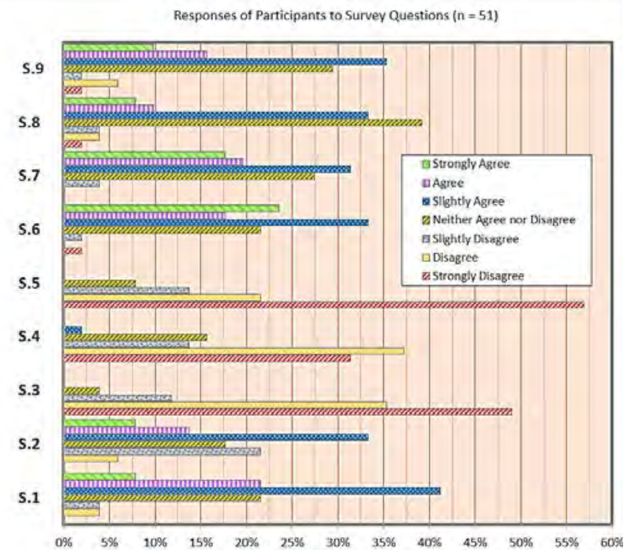

Figure 2. Students Reponses to survey

The next 2 questions (Q.5 and Q.6) strive to do a "before-and-after" comparison if students find the internship experience was aligned with their initial expectations.

Q.5 State <u>up to 3</u> things you most looked forward to; when you first embark on the Internship program in September last year.

Q.6 Did the internship met your expectation? On a scale of "1 (Most Dissatisfied)" to "10 (Most Satisfied)", please rate your experience in your internship with regard to the 3 things you identified above. Kindly explain your answer, for example, in what aspect of the internship that you felt your experience most satisfying or least satisfying.

For Q.5, students responses can be largely grouped into several main categories, some of which is a sharp contrast to another, for example in using the knowledge they learnt as compared to learning new things; gaining work experience in general, and hands-on experience more specifically; as compared to finding out one's career interest. There are some who cited money as the motivator, while others look forward to building networks. This just shown the wide range of aspirations of our students from their internship.

In relation to Q.6, a majority of students gave high scores for level of satisfaction: there are a total of 41 students who gave a score of 7 or above, with up to 7 students gave perfect 10! These students invariably cited good working environment and relationships with supervisors and colleagues as the main factors. Even the 1 student who gave the lowest score of 1 acknowledged that it was the job scope that was boring that contributed to the low score. The student even took the trouble to explain that a score of 8 would have been given for “nice and friendly people”.

We are also acutely aware that not all our students get to work in chemical plants. Even when they were assigned to a chemical company, many ended up working in laboratories instead of doing field work in the chemical plant. Part of the reason is that most companies are not willing to take on additional risks of having non-employees in the processing areas; and perhaps to avoid any “inconvenient” responsibilities should the unfortunate happened. As such, the next 2 questions (Q.7 and Q.8) try to elicit students’ feeling in the situation that there is a “mismatch” between expected placement and actual posting; and how one reconcile his/her notion of professional identity.

Q.7 You may be assigned to a chemical company, but did not have the opportunity to work in the plant. For example, you are assigned to work in the laboratory instead, or doing some quality improvement related work, or you may be assigned to research institution. Did that change your perception of what it takes to be a Chemical Engineer? Explain in detail how you deal with this situation. On the other hand, if you are doing work in the plant, explain how that reinforced your perception of being a Chemical Engineer.

Q.8 On a scale of “1 (None at All)” to “10 (Very Much)”, rate how you feel your internship experience had contributed to your notion of professional identity of being a chemical engineer. Kindly explain your answers to the above, for example, in what aspect of the internship that you felt your experience most satisfying or least satisfying.

The findings showed that our students are rather ambivalent about not being able to actually set foot into chemical plants. Albeit 3 “questionable” entries, most still reported that their perception of what makes a chemical engineer remained unchanged. From the postings, many were in fact worked in the laboratories, mostly product testing and process improvements. Many explained that they understood the broad-based nature of chemical engineering, and see the posting as a means of gaining work experience. A handful of them linked their experience to laboratory works back in campus, and some also see the importance of their work as a form of quality assurance in relation to the overall manufacturing processes. This can be seen from Figure 3, where a significant percentage of students scored 7 to 10.

The second last question (Q.9) tries to ascertain if students can link their internship experience with development of professional identity as chemical engineer.

Q.9 Reflect on your overall internship experience in helping to develop or failing to develop the professional identity as a Chemical Engineer.

Explain aspects of your internship experience (e.g. the work that you do) that contribute to the development of your perception of professional identity as a chemical engineers.

On the other hand, if you felt your internship experience did not contribute much to your notion of professional identity of a chemical engineer, explain how you persist in completing the internship program, e.g. how you reconcile your internship experience with your study in DCHE.

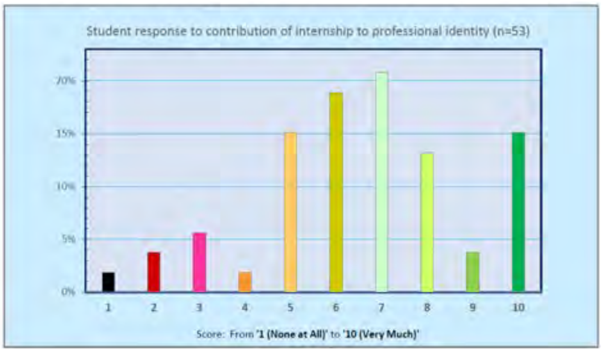

Figure 3. Contribution of Internship to Formation of Professional Identity

Here it becomes evident that students faced difficulty making the link between internship experience and professional identity. From the responses, 17 students did not addressed the question posed, and their input were discarded. There were 8 who felt that the internship did not contribute to their sense of professional identity, and reason cited were nature of work: mostly just laboratory work, manual work, sampling work, and doing work not related to chemical engineering. Of the 28 who responded positively, only 10 students mentioned continual improvement (quality assurance) and improving safety. The rest tend to associate the notion of professional identity with the broad job scope (6 responses) or immediate work done on specific tasks or area of focus (8 students). 3 students cited learning from others, and most interestingly, there is 1 student who said that while the internship provided him (or her) with a good sense of identity of a chemical engineer, the student had said that this will not be a career for him (or her).

The last question (Q.10) asked students for their views on how the internship program can be further improved.

Q.10 Is there any improvements that you think we can make to the Internship program or other modules in DCHE to enhance the development of professional identity as a Chemical Engineer? Please give us your suggestions and be as detailed as possible.

This question garnered the least responses, with 21 students replied ‘Nil”, or left the answer blank. 2 answers did not address the question and were discarded. For the rest, responses can be grouped under 3 main headings: (a) “Matching” issue (14 responses) of which 7 were related to issues on what was learnt in school compared to what they do at the workplace, and 7 on giving students more information upfront on the nature of internship, (b) course content that provides more exposures, e.g. laboratory hands-on sessions, different work scenarios, and physical plant visits (11 responses) and (c) Miscellaneous (5 responses). It can therefore be seen that notwithstanding that many students accepted laboratory work as part or bulk of their internship experience and gave high scores for their internship experience, the preference and greater interest still lies in process-related work. The most suggestions on "matching" issues centers around students wanting more internship placements relevant to the field of study. Many students also wanted to know the nature of work that they will be doing before commencement of internship.

The findings from this work indicated that experience from internship does shape the professional identity of our students. However, such development of an individual's professional identity depends on a range of factors. The findings indicate that whilst internship can be a major contributing factor in its development, other themes did emerged that can influence the development of professional identity. Each internship experience is unique in its own way, affecting students to different extent in a range of outcomes not restricted to the development of one's professional identity, for example, presence of company mentor, role of liaison officer, nature of job, expectation of students (including self-interest), company supervisor perception of students, just to name a few.

Enhancing Formation of Professional Identity in Students: CDIO Revisited

These findings indicate that we need to be more proactive in developing our students' notion of professional identity. However, despite the abundance of publications on professional identity, there is currently a dearth of publication on how to systematically design an engineering curriculum to develop one. To this end, we again turn to the CDIO Framework to investigate how development of professional identity can be strengthened. The use of scenario-based learning in DCHE is a good start, and more effort can be invested to bring out unique aspects of chemical engineering that can help students shaped their professional identity during the course of engaging in these learning activities. This is done by revisiting the 2 components of the CDIO Framework, namely the Syllabus and Standards.

The CDIO Syllabus has quite comprehensively covered various aspects of skills and attitudes that students need to develop to become a professional, such as *2.5.2 Professional Behaviour*, and *2.5.4 Staying Current on the World of Engineering*. These are supported by various other personal and interpersonal skills and attitudes for example, *2.4.6 Lifelong Learning and Educating*, *2.5.1 Ethics, Integrity and Social Responsibility*, and 3.2.10 *Establishing Diverse Connections and Networking*. These outcomes had captured much of what the Royal Academy of Engineering (RAE) terms the "Engineering Habits of Mind" (RAE, 2014), even though the term professional identity is not used.

In terms of CDIO Standards, the DCHE internship can be seen as an extension of an in-campus integrated curriculum (Standard 3) to provide students with an initial exposure of the real-world working environment. Students are provided with first-hand opportunity to appreciate how the engineering education they received in school are applied in the actual manufacturing or production environment (Standard 1). The workplace itself can be considered as "beyond-the-school learning environment" for students (Standard 6). As interns, they can be viewed as engaging in workplace learning where they get to demonstrate in an authentic workplace setting various different personal, professional and interpersonal skills developed in school. In fact, a student's daily interaction with company employees can be viewed as a form of Integrated Learning Experiences (Standard 7) where these skills are used in carrying out their assigned tasks. Needless to say, students are engaged in active learning (Standard 8) every day that they are in the workplace. As for the project component, the level of complexity varies in accordance with the project(s) requirements as assigned by the companies to the interns and ideally, can be viewed as Design-Implement Experiences (Standard 5) with different permutations of the elements of Conceive, Design, Implement and Operate. However, given that the internship only has a duration of 22 weeks, this may not provide sufficient time for students to be involved in all the four stages of conceiving, designing, implementing, and operating a process, product, system, or service. Existing internship assessment (Standard 11) especially that by the company supervisor, can be revised to focus more on demonstration of desired professional skills

Existing DCHE curriculum can be reviewed to provide a more seamless connection to prepare students for their internship experience in Year 3. What this entails is that modules in Year 1 and Year 2, including the 4 skills-based modules, need to be enhanced to help students make explicit connection to professional identity development from what they learn in each learning task. This can be as simple as tweaking existing integrated learning experiences to help inculcate a sense of professionalism in the work done. As noted earlier, with many tasks already designed for integrated learning experiences using scenario-based learning, it is not expected that many new learning tasks need to be designed from scratch. Insights can also be obtained from students' internship project reports, reflection journals and weekly task records; which they had to submit. There is a wealth of information that can be mined from such documents to reveal various workplace scenarios that can be adapted for classroom learning, or as part of liaison officers' briefing to students. Alternatively, a 1-day pre-internship workshop can be contemplated, with compulsory attendance by all students. Efforts can also be directed towards improving current approach to FYPs (Standard 5) to draw out aspects of professional identity from students' work. This may be more challenging in view that all FYPs are obviously different to begin with, and not all are industry-sponsored.

Lastly, lecturers themselves need to be equipped with right skills to facilitate professional identity development in students, starting with a good working definition of professional identity for diploma-level graduates in the context of working in the chemical industry. Various staff development programs can be introduced for example in designing integrated learning experiences that present realistic workplace issues (Standard 10), or in mentoring students in carrying out effective reflections to achieve a deeper working understanding of their learning experience to make connections to professional identity as chemical engineers.

Conclusions

Post Covid-19, literatures had started appearing discussing the impact of the pandemic on professional identity formation. Most of them not surprisingly, are from the medical profession (see for example Luman et al, 2022; Moula, et al, 2022). The findings reported largely still positive impact perhaps because of the unique role played by members of this profession during the pandemic. This may not be the case for other disciplines, as our findings had shown. This paper argued that the development of professional identity among students needs to be planned, and that students need to be made explicitly aware of how their learning experiences not as students, but as future professionals. This paper shared how the CDIO Framework can be used to guide the review of existing DCHE curriculum to enhance the development of professional identity among its students during the entire duration of study, which is then further sharpened during their internship.

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Early Science and Engineering Education by Regional Cooperation with Traditional Craft in Fukui KOSEN

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Abstract

Fostering next-generation scientists program has been run by National Institute of Technology, Fukui College (Fukui KOSEN) since 2022. The program aims to develop the skills of young people with exceptional aptitude and interest in mathematics and science and to create future leaders in the science and technology fields. The Japan Science and Technology Agency, JST, is a sponsor of the "Fukui KOSEN type PBL for collaboration between traditional industries and digitalized generations" initiative.

PBL, or problem-based learning, is used in Fukui KOSEN to help students develop their power of execution and drive for their coursework. They watch businesses in the area around the school and analyze business issues as they study. After that, they present their ideas after deliberating on solutions in groups.

This program involves similar process for about 40 elementary and junior high school students to cultivate capacity for problem-solving and innovation for 2 years. In the first year, students of the program join workshops in traditional craft centers near Fukui KOSEN such as Echizen Japanese paper and Echizen traditional chest, and understand histories, techniques and present problems. Students also learn general and special subjects including ICT and IoT provided by Fukui KOSEN. Through the activities and some presentations about their interests, they decide the theme of sequential study.

Then 10 students who can take the second year are shortlisted among 40 students in the first year. Each student is assigned to Fukui KOSEN laboratory working on related to their own theme, and studies supported by teachers and tutors. Finally, students who have completed the course can receive certificate of "Junior Doctor".

So far, we had to change some workshops and lectures to remote operation due to COVID-19. However, we have found the validity of this program because participants made great presentation valued by external assessment committees.

In this paper, we describe the program detail even in COVID-19 situation.

Keywords: *Early education, PBL, Traditional craft, Regional cooperation, IoT, ICT*

Introduction

There are worries about a workforce shortage in several industries in Japan, where the birth rate has been decreasing recently. This is particularly apparent in regional cities, where the dropping birth rate is quickening and many local industries are starting to suffer from a severe labor shortage. Numerous traditional industries, including Echizen Washi, or Japanese handmade paper, Echizen lacquerware, Echizen pottery, Echizen traditional chests, and Echizen cutlery, are concentrated in the Tannan-area of Fukui Prefecture, where the National Institute of Technology, Fukui College (Fukui KOSEN) is situated. Additionally, the production of eyeglass frames and the textile sector have grown to be emblematic of contemporary Fukui Prefecture. There is a severe lack of successors in these established industries as well.

Increasing labor productivity is one approach to this issue. In order to do this, digital transformation is being addressed in a number of industrial areas. Additionally, the development of innovative human resources is essential for future regional revival because they can produce new value.

Japan Science and Technology Agency (JST) is conducting the Fostering Next-Generation Scientists Program, also known as "Junior Doctor Training School" in Japanese, with the goal of developing outstanding human resources. The program seeks to identify elementary and junior high school students with high motivation and outstanding abilities and to certify and support projects that support systematic development plans to further develop their abilities.

On the other side, community engagement with KOSENs is stressed. According to Kaneshige et al. (2007), local KOSEN has demonstrated cooperative efforts. In the creative subjects assigned to each of the main and major courses, Fukui KOSEN is creating Problem Based Learning (PBL) type lessons. Students participate in workshops and company visits connected to these traditional industries in the class. They also propose solutions to issues raised during the course while hearing the viewpoints of businesses and create prototypes. We have discovered that these classes are successful since student-generated ideas have excelled in KOSEN design competitions. According to Furukawa et al. (2016), a university collaborates with a major corporation to carry out PBL. In the instance of Fukui KOSEN, it is distinguished by collaboration with small companies in education.

Fukui KOSEN has therefore been establishing Junior Doctor Training School under the name "Fukui KOSEN type PBL for collaboration between traditional industries and digitalized generations" since 2021. The project is aimed at digital native elementary and junior high school pupils. Our PBL activities give students a taste of traditional industries by applying our expertise in technological teaching. Additionally, it aspires to produce human resources that can contribute actively and creatively to the neighborhood and generate new value.

In this paper, we describe contents of the activities and valid the effects.

Planning of Collaboration

To collaborate traditional crafts around Fukui KOSEN, we had searched alliance partner. Then, we found a workshop event in traditional craft studios for sustainable community by an organization called “RENEW.” Fortunately, the undergraduate student in Fukui KOSEN was helping with this RENEW event, and we were able to meet with the chairman of the RENEW. Since 2015, RENEW has been holding events such as studio tours, hands-on workshops, craftsperson symposium, focusing on traditional crafts every year. Nearly 100 workshops and companies exhibited, and a total of more than 30,000 people, including those from inside and outside the prefecture, visited to events. We consulted whether it would be possible to conduct an attractive studio experience-type workshop that has been held at RENEW event in the Junior Doctor Training School. We received a reply that RENEW would like to be involved in the "education" part, and we were able to obtain cooperation with many traditional craft studios for the project through RENEW.

Contents of the Course

The institute of Junior Doctor Training School must prepare fostering program in 2 divided stages. We have planned that students take classes in Fukui KOSEN and have workshops in traditional craft studios as the first stage. We also planned that each student is assigned to Fukui KOSEN laboratory working on related to their own theme, and studies supported by teachers and tutors as second stage.

The program in first stage is shown in Table 1. The number of classes is greater than other institutions conducting Junior Doctor Training School. Many classes are reconfigured for elementary and junior high school students with reflection of experience and knowledge of previous extension lectures.

The requirements for completing the first stage are to take all compulsory courses and 7 elective courses out of the 30 courses mainly implemented by Fukui KOSEN.

Table 1. Title of courses in the 1st stage

Title of course	Type	Max No. accepted
Research Ethics	Compulsory	40
Thinking Method	Compulsory	40
Various Tools and Roles	Compulsory	41
Machine Training Factory Tour	Compulsory	41
Digital Manufacturing	Elective Compulsory	20
Model Plane Making with Laser Cutter	Elective Compulsory	20
Campus Tour	Free	41
Programming for Beginner	Compulsory	41
What’s ICT? What’s IoT?	Compulsory	41
Math and Technology in Egg Drop	Elective	25
How-to 3D CAD	Elective	25
Making Toy Powered by Thermal Energy	Elective	20
Electronic Circuit with Block 1	Elective	12
Electronic Circuit with Block 2	Elective	12
Electronic Circuit with Breadboard	Elective	15
Data and Error	Elective	20
Measurement and Control by IchigoJam	Elective	20
Web Design and Web Game Application	Elective	41
Making Original Bookmark	Elective	10
Let’s study Surfactant	Elective	20
Pigment Synthesis	Elective	20
Drone Flight and 3D Model Creation	Elective	20
Architecture with MR	Elective	10
Science by Construction	Elective	20
Wonder of Numbers	Elective	20
Sports Data Science	Elective	10
Let’s look at Sound	Elective	15
Traditional Industry from SDGs	Elective	10
Dialect Description by Interview	Elective	20

After elective courses, students must submit report. At the same time, students must join at least 2 traditional craft workshops and 2 presentations at the middle and the final. If student achieve the requirements, they can receive the certificate “Junior Master of Fukui KOSEN.”

We have given students guidance on the presentation theme which means research title in the second stage. The guidance policy is merger the knowledge from the coursed in Fukui KOSEN and interest in the workshops.

Students who achieve excellent grades in the first stage can proceed to the second stage in the next year. In the stage, students are assigned to laboratories of Fukui KOSEN according to the research theme of each student. They come to Fukui KOSEN on weekend and after school to carry out their research, and are supported by teachers and student tutors.

Progress and Validation

In first year, 2021, we have held only first stage. After document screening of 68 applicants, 4firstudents were accepted. Figure 1 shows the situation of the workshop in Echizen lacquerware studio. Many students had taken a note and ask their questions religiously.

Table 2 shows a part of the title of the middle presentation held face-to-face in Dec. 4th, 2021. Many titles are vague in this stage yet. After the middle presentation, the course related to thinking method was held as one of the compulsory courses. Table 2 also shows a part of the title of the last presentation in March 2first, 2021. The final presentation had been conducted with remote conference system by considering the COVID-19 infection despite the plan of face-to-face with posters in our school gym. So, students who can prepare prototypes and handmade poster might have regretted. Figure 2 shows the situation of final presentation.

Finally, 39 students out of 41 could receive the certificate “Junior Master of Fukui KOSEN,” and 29 students except 9th grade students who cannot be a subject wanted to advance the second stage in next year.

In second year, 2022, we have held first stage for new 4firstudent and second stage for 10 students shortlisted among 4firstudents in the first stage.

The 10 lines from the top of Table 2 shows all themes of the final presentations by the students in the second stage. The theme proposed by the students in the last of the first stage was the basic theme, but the final theme also took into consideration the specialties of the teachers. At the time of the presentation, prototypes and system productions were carried out for all themes, and it was observed that the high motivation of the students continued and the growth of their abilities was seen. In particular, two researches, “Collaboration with Washi industry using pH-responsive pigment extracted from Trifolium pratense” and “Disseminating Information on Traditional Crafts Considering Individual Preferences”, received awards for excellent study at the "Science Conference," an event attended by representatives of Junior Doctor Training Schools nationwide. Both themes were the fusion of young points of view unique to students and the specialized knowledge and skills of Fukui KOSEN, and research content unique to this project. We find that this result shows the high effectiveness of this project.


Fig. 1 Workshop in Echizen lacquerware studio


Fig. 2 Final presentation in first stage

Conclusions

We think that we were able to develop problem-solving skills linked to traditional industries in elementary and junior high school students by implementing Junior Doctor Training School that applied Fukui KOSEN PBL.

Continued activities are required in the future because this project can receive support for 5 years from JST. However, the number of applicants for the second year decreased from the first year to 41, and all of them passed the selection process and proceeded to the first stage. Among them, only 1firstudents wished to proceed to the second stage, which was also less than in the first year. In order to secure highly motivated students, it is necessary to consider not only securing the number of applicants but also improving the training program to make it more attractive.

Students in Fukui KOSEN are participating in this project as tutors. It is thought that teaching elementary and junior high school students will lead to their own growth.

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Table 2. The title of presentations and studies

Grade	Title of the middle presentation in 1st stage	Title of the last presentation in 1st stage	Title of study in 2nd stage	Department of Adviser
8	Artisanship and Modern Technique	Antibiotic and Hygroscopic Washi	Development Washi using research of Nostoc commune	Chemistry and Biology
8	Traditional Craft & English	Deliver Traditional craft in Tannan in English	Study on Disseminating Information on Traditional Crafts Considering Individual Preferences	Electronics and Information Engineering
8	Lacquer & Bridge	Bridge Build-up with Lacquer	Study on Crack Repair of Concrete by Kintsugi Technology Using Lacquer	Civil Engineering
8	Coloring Titanium Plate & Knife	Fancy Knife & Cooking Skill Up	Research on corrosion of colorful kitchen knife	Chemistry and Biology
7	Echizen Chest & Echizen Cutlery	Echizen chest & Echizen cutlery	Kitchen Knife Stand incorporating the design concept of Echizen chests of drawers	Mechanical Engineering
7	Surfactant & Washi	Insoluble Portable Washi Soap	Making Portable Soap Made of Echizen Washi and Evaluation	Chemistry and Biology
7	MR & Echizen Chest	Fukui traditional craft by VR	Development of Teaching Materials for Inheritance of Fukui Traditional Crafts Using Mixed Reality	Civil Engineering
7	Cutlery & Pigment Synthesis	Cutlery for Health and Environment	Collaboration with Washi industry using pH-responsive pigment extracted from Trifolium pratense	Chemistry and Biology
6	Echizen Washi & Programming	Japanese Traditional Crafts from Fukui to the Future	Metaverse development to disseminate traditional crafts in Fukui	Electronics and Information Engineering
6	Making Toy Powered by Thermal Energy & Knife Village	Big Pop Pop Boat by Thermal Energy	Larger Pop Pop Boat for My Ride	Electrical and Electronic Engineering
9	Sports Data & Eyeglass	Sports Data & Eyeglass	(Not applicable)	-
5	Lacquerware & IoT	Food and Health Problem Solution by Echizen Lacquerware	(Unsuccessful)	-
4	Echizen Cutlery & Laser	Stronger and Lighter Echizen Cutlery	(Unsuccessful)	-

SDGs hackathon event focused on AI/IoT with M5Stack

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Abstract

In this presentation, we will discuss a hackathon event focused on Sustainable Development Goals (SDGs) as a social issue, which employed AI and IoT technologies using the M5Stack microcontroller series. The event was organized by faculty members from Kanazawa University, Kanazawa Institute of Technology, Hokuriku University, and National Institute of Technology (Ishikawa College), along with several local companies. The hackathon consisted of three stages. The first stage was a one-day ideation workshop, during which participants learned about Sustainable Development Goals (SDGs) and technology, chose the SDG topic they wanted to address, and engaged in team building. The second stage was an online training session, where each participant received hands-on training on how to use the M5Stack. In the third stage, lasting two days, participants worked on creating solutions to SDG-related problems. Throughout the hackathon, 27 participants worked on seven different projects. Although Raspberry Pi is a well-known hardware platform for learning AI/IoT, and many hackathons have used Raspberry Pi, this event utilized the M5Stack. The M5Stack is a compact microcontroller module that integrates peripherals such as an ESP32 with Wi-Fi and Bluetooth wireless communication capabilities, color LCD display, buttons, speaker, microSD card slot, and battery into a 5cm x 5cm square package. The M5Stack can be developed using UIFlow, a visual programming tool with a GUI, which allows even inexperienced programmers to learn from the documentation. There are numerous modules, such as sensors and actuators, that can be easily connected to the M5Stack. Additionally, a wide variety of libraries are available for using the sensors, making it accessible for those with no experience in electronics design to tackle the project. This presentation shows the prototypes created by the students and the feedback received from the event. According to the results of a questionnaire given to the participants, more than 80% of the respondents rated the event as excellent, while the rest considered it good. All participants answered feedback expressing their satisfaction with attending the event.

Keywords: *AI/ IoT, SDGs, hackathon, M5Stack*

Introduction

As part of the Ministry of Internal Affairs and Communications (MIC) project to improve the literacy of young people developing new IoT devices and services, the Ishikawa District of the Web x IoT Makers Challenge, a skills development event for students and young engineers to enhance their understanding and proficiency in IoT, has been organized as a hackathon event since 2019. A hackathon is an event where individuals or teams come together to work on solving a problem or creating a project within a specific timeframe, usually ranging from a few hours to a few days.

Materials : M5Stack

In this event, the M5Stack was utilized. M5Stack is named after the initials of "Modular 5cm x 5cm Stackable." M5Stack is also the name of a technology company located in Shenzhen, China.

We selected the M5Stack as the most suitable option for IoT prototyping. The M5Stack is equipped with the ESP32, which is one of the most popular products with a communication module. The ESP32 within the M5Stack features built-in Wi-Fi and Bluetooth, enabling it to connect to the internet and communicate wirelessly with peripherals. This makes it easy to create applications that send and receive data to and from servers. Many existing microcontroller boards do not have a user-friendly output interface. The M5Stack has a built-in screen, making it easy to display information. This screen is also very useful for debugging during development. The M5Stack comes equipped with three buttons from the start. Most existing microcontroller boards have bare boards, which have disadvantages such as corners and terminals that can scratch hands and peripheral devices, and being easily broken by shocks when carried around. The M5Stack is enclosed in a case, making it durable and visually appealing. This case also adds durability, with all buttons and terminals located on the exterior. As the M5Stack has a built-in battery, it can be used without power supply wiring, expanding its range of applications. M5Stack can be developed using UIFlow, a visual programming tool with a GUI, allowing even inexperienced programmers to learn from the documentation. The product lineup includes numerous modules, such as sensors and actuators, which can be easily connected to the M5Stack. Additionally, a wide variety of libraries for using these sensors are available, enabling even those with no experience in electronic construction to tackle projects.

Raspberry Pi is well-known hardware for learning AI/IoT, and many hackathons have utilized Raspberry Pi. When comparing Raspberry Pi and M5Stack, there are several factors to consider. M5Stack is easier to use and more accessible for beginners, as it comes with built-in sensors, a touchscreen display, and a user-friendly programming environment. It also has a more compact design and can be easily integrated into wearable devices or other small-scale projects. Arduino is also a well-known electronic hardware, but it cannot be used for IoT without a communication module.

Web x IoT Makers challenge, the first year

In the first year's Hackathon event, we held a two-day hands-on session. One month later, we conducted a two-day hackathon. The event was sponsored by the Ministry of Internal Affairs and Communications and was organized by a steering committee consisting of staff from Ishikawa Prefecture, Kanazawa City, local companies, and faculty members from various universities and Ishikawa KOSEN.

In the first year, this hackathon focused on solving local and familiar problems. The 24 participants were divided into six teams based on the theme they wanted to explore. The Grand Prize went to Garbage Collector, a garbage collection robot that determines its route using information from a ceiling-mounted camera and moves around the desk, avoiding obstacles to collect garbage. All six teams were outstanding.

Web x IoT Makers challenge, the second year

In the second year, 2020, we conducted the event entirely online to prevent the spread of COVID-19. Since the previous event was successful, participants invited others to join them, and the number of participants reached as high as 36. In mid-November, M5Stack lecture materials were posted online, allowing participants to study at their own convenience. Although there were times when participants were unable to follow the lectures due to differences in their PCs and internet environments, they were able to ask questions frankly in the online message group, in which both the lecturers and all participants participated, and the lecturers were able to provide appropriate support. We provided the new M5Stack Core2 instead of the M5GO IoT Starter Kit. We also provided some sensors, such as environmental sensors (temperature, humidity, and barometric pressure sensor unit), ToF distance measurement sensor unit, optical sensor unit, digital RGB LED Strip, servo motors, and a conversion board. M5Stack also provided the new AI Camera "M5StickV" and "UnitV" with a dual-core 64-bit RISC-V CPU and an advanced neural network processor. The main difference between UnitV and M5StickV is that the LCD, battery, and gyro sensor are no longer included, making it smaller and lighter.

We also provided tutorials. If participants didn't understand something, our staff members were always available to answer questions on Discord.

The 36 participants were divided into 6 teams with different affiliations to create their works online. Zoom, Slack, and Miro were used as online communication tools. The event kickoff and idea workshop were held via video conference on Zoom. Associate Professor Sekiya of Hokuriku University served as the facilitator. The morning session was spent introducing themselves and practicing the functions of the videoconferencing and whiteboard-sharing applications (Miro), setting the stage for the discussion that followed. The theme of the discussion was the free exchange of opinions on troubling experiences around us. Participants voiced a variety of opinions, not limited to those related to COVID-19, and the repeated discussions with different members allowed participants to think about the issues in depth. In the end, six teams of three to seven members were formed to discuss and organize ideas for a hackathon project. After the ideation workshop, the teams continued to discuss and prepare for the hackathon three weeks later in their online groups.

The Grand Prize went to a multifunctional device for online communication that enables users to check the availability of the caller, provide topics of conversation, and read the facial expressions of others even when the video is off, and was recognized for its use and implementation of M5Stack.

The other team developed a bear notification system. With bear sightings and reports of bear damage increasing in the prefecture, a system was developed to prevent damage before it occurs. The system detects bears using AI cameras installed in the city, plays music from M5Stack to repel bears, and sends GPS information to Ambient to alert residents of the location of bears. The location of bear appearances can be stored in Ambient and displayed as a graph. Cameras and M5Stacks will be installed under streetlights where people are likely to be present, and in areas where there are power sources for farming. The other five teams also demonstrated a good understanding and use of M5Stack, and after discussion among the judges, all teams were awarded special prizes.

SDGs Hackathon, the third year

This Web x IoT makers challenge event has been held for two years by the Ministry of Internal Affairs and Communications since 2019. However, the Ministry of Internal Affairs and Communications (MIC) decided not to provide a budget for this event in 2021. Despite this, we believe the event is worth continuing, so we received funding from the Shibuya Science Culture and Sports Foundation, a company in Ishikawa, and held it independently under the name of SDGs Hackathon.

The hackathon was divided into three events. The first event was a one-day idea workshop, where participants learned about the Sustainable Development Goals (SDGs) and technology, decided on the SDG theme they wanted to address, and engaged in team building. The second event was an online training session, where each participant received hands-on training on how to use the M5Stack. In the third event, which lasted two days, participants worked on creating solutions to SDG issues.

The SDGs, Sustainable Development Goals, were unanimously adopted by 193 member countries, including Japan, at a summit held at UN headquarters in 2015 as common global goals, setting forth visions and tasks aimed to be achieved by 2030.

The hybrid format was a good combination of what we had done online last year and offline two years ago. The hybrid format of online and in-person participation was used, and everyone seemed to be able to use Miro very well. I felt that this kind of hybrid approach is becoming more effective in idea-making and communication than the usual online-only or face-to-face approach. At first, I was worried about whether the students would be able to use these tools, but they were all able to use them without any confusion at all.

27 people participated in the event, which consisted of 7 teams. Since all the students who participated in the program made great achievements and put in a great effort, we did not give out awards for the best or ranked awards, but created one certificate for each participant and presented them to them. Our staff members came up with names for the awards based on their ingenuity, and at the awards ceremony, they all commented on good points of their works.

Results and Discussion

From the results of a questionnaire (Table 1) given to the participants who attended the event, more than 80% answered that the event was excellent, and the rest responded with good. Additionally, all the participants gave feedback that they were glad to have attended the event.

Table 1. Results of a questionnaire

	%
Excellent	82.4%
good	17.6%
fair	0
poor	0
very poor	0

The following is a list of the reasons given in the free response.

- Because I had a lot of fun making things with people from other schools. Also, I was able to make new discoveries by discussing my ideas with various people.
- I have not had many opportunities to speak in front of people recently, so I was glad to be able to give a presentation in front of so many people.
- I enjoyed talking with people I had never met before.
- It had been a while since I had created my own work, and I enjoyed it because I was able to do so.
- It was good to talk with people from other universities and technical colleges that I don't usually talk to, and to be stimulated by them.
- Because I gained experience in solving problems related to the SDGs with IT.
- It was a good stimulus and increased my motivation.
- I was able to meet students from other universities and working people.
- I could understand the program even as a beginner.
- Seeing and hearing about various works was a good stimulus.
- I was able to understand how to use programming techniques, which I had only studied and did not know how to use, and how fun it is to create things with programming.
- The people around me were excellent, and it was very stimulating to exchange opinions and create things together.
- Because I acquired programming skills.
- Because I was able to experience the setup of a team to create a product in a short period of time.
- Because I was able to experience development with multiple people.
- Because I was able to create something by programming in earnest.
- Because I was able to gain new skills and knowledge.
- Because I could cooperate with people I had never met before and develop communication skills.
- I was able to take on a big challenge with strong support.
- The experience of thinking about social issues from a new perspective of manufacturing was very stimulating.
- I was able to think about solving issues together with my team members, and we were able to create ideas that had never existed before.
- Because there were many people from different fields that I have been involved with, and I got a lot of new stimulation.
- Also, I felt that we had a good relationship where we could honestly ask each other about things we didn't understand and teach each other.

Table 2 shows the results of the questions asked about what they learned from the hackathon.

Talbe 2. "What do you think you learned from participating in the hackathon."

Questionnaire item	# of People (%)
Experience developing with a team	14（82.4%）
Experience in bringing ideas to life	12（70.6%）
Control skills with M5Stack, sensors, etc.	12（70.6%）
Experience with prototyping in short timeframes	11（64.7%）
Communication skills	8（47.1%）
Programming skills	7（41.2%）

Table 3 shows the good points about the content of this hackathon.

Table 3. Good points about the content of this hackathon.

Questionnaire item	# of People (%)
Staff Response	15（88.2%）
Theme, subject matter	14（82.4%）
Assistance with material costs	14（82.4%）
Actual equipment used (M5Stack)	11（64.7%）
Style of presentation	11（64.7%）

Table 4 shows the result of a question about the direction participants would like to take in the future. Although small in number, it was surprising to see that about 30% of the participants indicated that they would like to start their own businesses.

Table 4. The direction you would like to take in the future

Questionnaire item	# of People (%)
I want to work on IoT in my private life	13（76.5%）
I want to become an engineer who can handle IoT as a job.	10（58.8%）
I want to plan services using IoT as my job.	6（35.3%）
I want to start my own business.	5（29.4%）

The following are the responses to the question asking if there is anything you would like to learn or improve your skills in the future.

- Python, Ruby on Rails, HTML & CSS
- I would like to be able to do hardware (circuit design) as well as software.
- Communication technology (UDP, etc.)
- I would like to participate in any workshops on stm microcontrollers, RX microcontrollers, etc.
- I would like to get used to it by creating and executing some programs only by myself.
- I would like to make an effort to grow in terms of knowledge, such as technical terms and techniques.
- I want to learn further programming knowledge.
- I want to improve my programming skills using Python
- How to handle AI in Python About databases
- Machine learning systems
- I would like to try many things while I am a college student in a field that I usually don't have access to like this one.
- Programming techniques

The following is a summary of the feedback throughout the event.

- It was so much fun! Thank you!
- The staff provided positive encouragement and support during the event, which helped me to finish the whole thing.
- It was great, thank you very much.
- I enjoyed learning programming very much.
- The experience of creating and presenting a work in a short period of two days will help me to grow.
- It was nice to interact with people from other schools.
- The staff was very accommodating, the environment conducive to doing our best, and it was a very meaningful event!
- It was very good.
- I learned how to make the most of IT at this event.
- I have never had the opportunity to work with people who have different experiences and abilities in programming and computers, so I think it was meaningful to cultivate group activity experience in such a context.
- It was a very good experience. Thank you very much for creating such a place.
- I really received a lot of wonderful stimulation. Thank you very much. I'd love to participate again when you hold another one!
- Thank you so much to all the teachers who allowed me to attend the event and supported me. I was able to experience many things I have never done before and had a lot of fun.

Conclusions

lthough the 'Monozukuri' Hackathon 2023 was held after the deadline for abstract submissions and hence could not be included in the abstract, it took place at Hokuriku University in Ishikawa, Japan from March 18-19, 2023. This was the fourth annual event, with a total of 25 participants. The event, sponsored by Ricoh IT Solutions Co., continues to be well received, becoming increasingly established each year. It offers a valuable opportunity for students to learn about AI/IoT technologies in collaboration with various universities and regional companies.

Acknowledgements

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We would like to extend our gratitude to the many individuals and organizations that contributed to these events, including Prof. Junichi Akita of Kanazawa University, Prof. Minoru Nakazawa of Kanazawa Institute of Technology, Assoc. Prof. Akiko Sekiya of Hokuriku University, Lecturer Yuki Fujimoto of Hokuriku University, Krewit Corporation, iPublishing Corporation, and others.

DATA-INFORMED DESIGN THINKING FOR SUSTAINABILITY:
An Interdisciplinary Learning Approach

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Abstract

Data-informed design thinking (DIDT) is a collaborative approach to problem-solving that combines design thinking principles with data analysis. By incorporating a range of data sources, multidisciplinary teams can effectively address complex issues and develop relevant solutions that better meet the needs of end-users. The Apex Harmony lodge (AHL) project serves as a case study demonstrating how DIDT enhances student learning by helping them to ground their design solutions in evidence and data.

The project involved collaboration between students from different schools to enhance the liveability and sustainability of a residential healthcare facility for patients with dementia. The students used digital technologies to manage and integrate data and better understand and articulate architectural design and the physical environment. They also used the design process as a framework to integrate vast amounts of data and translate complex information into objective outcomes.

The empathy stage of DIDT involved research to gain an understanding of the needs of the users. The data collected informed the design, visualization, resulting in better-tailored solutions that improved the overall effectiveness of the design process. Students synthesized their research findings, analysed key information to generate and evaluate potential solutions, and prototyped and tested their solutions to ensure they met the needs and expectations of users and stakeholders.

The use of data analysis facilitated problem-solving by providing valuable insights into complex problems. It grounded designs in evidence and data, justifying design decisions and fostering accountability. Additionally, the interdisciplinary learning approach helped to nurture and train a new generation of critical thinkers and doers to be ready for our ever-changing job market.

Teaching DIDT to students is imperative due to the rising demand for data-driven decision-making in today's organizations. Adopting DIDT helps students create more efficient products and equip students with crucial skills for succeeding in the modern workplace while addressing user needs.

Data extracted from performance-based design analysis simulations such as air flow and solar analysis, energy-modelling, and carbon life cycle analysis, influenced the sustainable building design. The students used integrated spatial analytical models, including computational simulations, to quantify and measure sustainable design performance in AHL.

AHL Client engagement makes this Interdesciplinary learning (IDL) setting authentic for student learning, exposing them to the realities of work-life. In conclusion, DIDT is an effective approach to problem-solving and decision-making that leverages information to drive innovation.

Keywords: *sustainable design, integrative learning, industry engagement, interdisciplinary learning, data-informed design thinking, architectural design.*

Introduction

Due to rapid advancements in technology and automation, preparing students with the necessary skills to excel in the continuously evolving job market has become an increasing concern.The objective of this paper is to investigate how interdisciplinary learning can prepare students for success in the industry and how the integration of data analysis into the design thinking process can enhance the pedagogy of Design and Engineering, with a particular emphasis on the context of sustainable buildings.

Research has shown that interdisciplinary learning enables students to integrate knowledge and perspectives from different fields, resulting in a more comprehensive understanding of complex problems (Ney,Steven. Meinel,Christoph., 2019).

Interdisciplinary learning has been found to enhance students' problem-solving abilities, creativity, critical thinking, and communication skills. Moreover, it has been demonstrated that interdisciplinary learning prepares students for jobs that necessitate collaboration and adaptability (Self, J., & Baek, J. S., 2017). In addition, interdisciplinary learning plays a pivotal role in addressing the topic of sustainability, which is a fundamental aspect for the case study presented in this paper. By integrating knowledge, perspectives, and methodologies from various academic disciplines, interdisciplinary learning provides a multifaceted approach that acknowledges the complex and interconnected nature of sustainability challenges. This approach recognizes that a comprehensive understanding and effective solutions require collaboration and synthesis across diverse fields. (Zeltina, M., 2021).

The design thinking process is a systematic and iterative approach that involves problem-solving and decision-making to create innovative and functional designs. It typically consists of several stages, including research and analysis, definition of the problem, conceptualization and ideation, prototyping, testing, and refinement. The design thinking process, employed as a pedagogical approach for design students, provides a systematic framework to guide their learning (Brown, T., 2008)

This process is widely utilized across various fields to tackle complex problems and foster the creation of innovative solutions (Leifer, L., Plattner, H., & Meinel, C., 2013).

Utilizing the design thinking process offers several advantages in problem-solving and solution development (Kelley, T. R., & Knowles, J. G. , 2016).

- Creativity and Innovation: Design thinking encourages divergent thinking and fosters creativity by emphasizing exploration, brainstorming, and idea generation, thereby allowing innovative solutions to emerge (Brown, T., Katz, B., 2011).
- User-Centered Approach: The design process incorporates a user-centered perspective, ensuring that solutions meet the needs and preferences of end-users. This user-centric focus enhances the usability and acceptance of the final product or service (Ackermann, R., 2023).
- Iterative and Collaborative Nature: The design process follows an iterative and collaborative approach, allowing for continuous refinement and improvement. Feedback from stakeholders and end-users is gathered and integrated throughout the process, leading to better outcomes (Liedtka, J., 2014).
- Holistic Problem-Solving: The design process considers multiple dimensions and factors involved in problem-solving. It promotes a holistic understanding of the problem, leading to comprehensive and effective solutions (Sanders et al , 2008).

  Despite its strengths, the design process is not without limitations:
- Subjectivity and Bias: Design thinking relies on subjective judgments and individual perspectives. The identification and interpretation of user needs and preferences may be influenced by inherent biases, potentially limiting the diversity of solutions (Norman, D. A., 2013).
- Time and Resource Intensive: The design process is typically time-consuming and resource intensive. Extensive research, prototyping, and testing may be required, resulting in longer development cycles and increased costs (Kolko, J., 2018).
- Lack of Predictability: The iterative nature of the design process can introduce uncertainties and make outcomes difficult to predict. This lack of predictability can be challenging for organizations seeking concrete deliverables within fixed timelines.

Engineering students are typically trained in data collection and solution development techniques to address findings within their field. However, they often lack a comprehensive understanding of the contextual factors and problems at hand, as well as the ability to think creatively and innovatively.

Data-informed design thinking (DIDT) is a collaborative approach to problem-solving that combines design thinking principles with data analysis (Brown, T., Katz, B., 2011). It aims to use data sources to make the design process less subjective, more efficient, and more predictable.

Research has shown that integrating key data sources into the design thinking process leads to better outcomes in terms of product design (Buchanan, R., 2019) Furthermore, computer simulations that predict building behaviour can aid designers in identifying potential issues with their designs prior to implementation, thereby mitigating the risk of expensive errors. In the built environment industry, interdisciplinary and data-informed design processes have become standard practice. However, in the academic context, engineering and design are still taught in isolation. Moreover, it is crucial for future Design and Engineering professionals to possess versatility and adaptability in order to effectively engage in diverse fields of work that demand skills beyond their specialized area of expertise. The isolated approach to their respective fields may not adequately prepare them for the multifaceted challenges encountered in real-world scenarios (Bear, A. & Skorton, D., 2019).

The adoption of an interdisciplinary approach in education is vital in equipping students with the necessary skills and knowledge to meet the demands of future employment, which often necessitates a diverse skill set and the ability to integrate knowledge across various disciplines (Sanders et al , 2008).

Materials and Methods or pedagogy

The present case study delves into an interdisciplinary industry project that centres around designing a healthcare facility specifically tailored for patients with dementia. This project serves as the focal point for investigating collaborative interdisciplinary learning (IDL) initiative, which brings together the Diploma in Interior Architecture & Design (IAD) program from the School of Design and the Architectural Technology & Building Services (ABS) program from the School of Engineering at Temasek Polytechnic. The primary objectives of this collaboration were to provide students with practical exposure to industry settings, showcase the effectiveness of data-informed design thinking (DIDT) in enhancing student learning through evidence-based design solutions and identify the skills that students develop through IDL to prepare them for future employment opportunities. By examining this case study, we gain insights into the outcomes and implications of integrating interdisciplinary approaches and data-informed design thinking in the educational context, especially in the fields of architecture and architectural technology and building services.

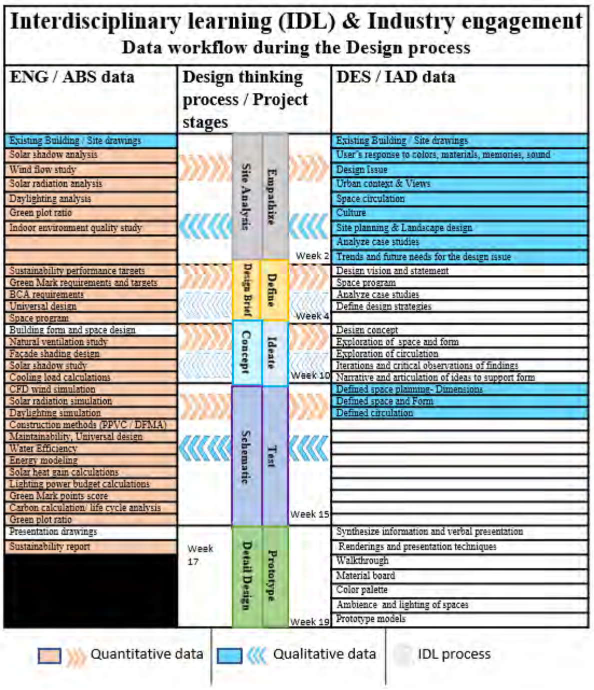
During the study, ABS and IAD students collaborated to improve the liveability and sustainability of the healthcare facility, with a specific focus on addressing the challenges and needs of dementia patients. The project encompassed all stages of the design process, commencing with site analysis and extensive research. This was followed by the formulation of the design brief, ideation of potential solutions during the Concept Design phase, prototyping of solutions during the Schematic Design phase, testing of solutions during the Detailed Design phase, and ultimately presenting the final design to the client for feedback. This feedback, in an industry setting, would serve as a foundation for refining the proposal.

During the Site Analysis and definition of the design brief stages, engineering students facilitated simulations of wind flow, solar and heat mapping of the site during different times of the day and year, while design students investigated the client and patients' needs, dementia, and its implications for Singapore's future. They also explored the urban context of the site and future developments for dementia institutions.

The ideation phase of the project focused on developing potential solutions to the design problem. The design students were encouraged to explore a wide range of potential solutions and ground their ideas in evidence and data. They were also required to consider the social and cultural implications of their design solutions and ensure they were appropriate for patients with dementia.

In the Schematic Design phase, design students were encouraged to define their ideas and transform them into tangible, well-defined forms. This phase involved the development of visualizations and technical drawings of the design solutions. Once the forms were reasonably defined by design students, engineering students facilitated the creation of 3D models for the designs and conducted simulations to test how the new designs would perform in relation to wind flows, solar orientation, and heat gains. The aim was for Design students to integrate these findings into their design process and utilize them to inform their design solutions. To accomplish this, we expected students to actively seek feedback from their peers and iterate on their designs in response to the feedback received.

During the detailed design phase, the design students further developed visualizations and created physical prototypes of the design solutions. They gained a more detailed understanding of their design solutions and began refining their ideas. Finally, the students presented their final designs to the client, who provided relevant feedback on the designs.



Results and Discussion

To gather data for this study, a multi-faceted approach was employed. Firstly, student submissions and final presentations were collected and analyzed (Self, J., et al, 2017).

These materials provided valuable insights into the students' learning and project outcomes.

In addition to the analysis of student work, surveys were administered to gather the perspectives of students on the effectiveness of the interdisciplinary collaboration and their learning outcomes (Donnelly, S., et al, 2019).

The surveys allowed for a deeper understanding of the students' experiences and perceptions related to the project.

Interviews, both with teachers and with IAD students, also played a crucial role in this qualitative analysis, providing rich, in-depth insights and perspectives from participants. The interviews enabled researchers to explore complex phenomena and gain a nuanced understanding of the subjective experiences and meanings attributed to them.

Furthermore, subject teachers conducted observations to gain valuable insights into the overall effectiveness of the interdisciplinary collaboration project and identify potential areas for improvement. These observations provided first hand findings on student engagement, effectiveness, timing of data exchange, and the learning process. The utilization of this multi-dimensional approach to data collection ensured a comprehensive and nuanced understanding of the impact of the project on student learning and the overall effectiveness of interdisciplinary collaboration.

The surveys and interviews conducted among IAD and ABS students provided valuable insights into their collaborative experiences and outcomes of the IDL project. The surveys highlighted the importance of diverse perspectives and thinking styles in enhancing the project, while also identifying communication difficulties as a notable challenge. ABS students reported skill development in visualization techniques and critical analysis. Challenges related to workload, motivation, timetable synchronization, and submission coordination were also observed.

The interviews with IAD students revealed positive aspects of collaboration with ABS students, including gaining an understanding of their responsibilities and receiving feedback. Challenges included partner commitment, communication difficulties, conflicting perspectives, misalignment in design approaches, and timing issues with submissions. Weaker students benefited from ABS input but experienced decreased ownership and control over the project. The IDL experience was stressful due to divergent requirements and expectations, but IAD students agreed that the data suggested by ABS students helped them solidify their concepts and propose more realistic solutions to the client.

The analysis of engineering students' work reveals significant improvements in their understanding of the subject matter, core skills, and specific design abilities. ABS students without IDL focus exclusively on incorporating technological advancements and designing for energy efficiency in buildings. ABS students, with their interdisciplinary learning (IDL) experience, were equipped to utilize data in order to inform design solutions and create designs that are more adequate and relevant. They also utilize comprehensive simulations for wind, solar, lighting, and façade design, considering factors such as aesthetics and human wellbeing Through interdisciplinary learning (IDL), ABS students are able to broaden their exploration of design solutions beyond environmental factors of sustainability. They also incorporate human factors into their considerations, thereby encompassing a more comprehensive approach to design. ABS students with IDL conduct life cycle analysis calculations and utilize collaborative software and communication platforms for real-time collaboration and streamlined interactions. They also incorporate design thinking principles and iterative processes into the environmental analysis. Overall, the findings highlight the positive impact of IDL on ABS students' design skills and their ability to work collaboratively using advanced tools and approaches.

Feedback provided by the client indicated that the students effectively addressed their realistic needs and inspired them with tangible innovative solutions.

Despite the numerous benefits reported by students, such as the preparation for the work environment and the enhancement of critical thinking and communication skills, there are important learning points that should not be overlooked. These should be incorporated into the design of the Interdisciplinary Learning (IDL) experience to further improve the students' learning journey.

According to the feedback provided by design teachers, challenges emerged due to inherent disparities in approaches and perspectives between design and engineering students. Design students exhibit a tendency towards a conceptual orientation, adopting a holistic view of the collected data, while Engineering students lean towards a more focused and specific mindset (Tan, V., et al, 2019), primarily concerned with translating the gathered information into tangible design elements. Consequently, Design students engage in exploring various iterations of intentions and conceptual ideas for the overall design, while Engineering students concentrate on specifying precise sizes and locations of components such as fans and openings. This divergence in perspective created misalignments regarding the perceived significance of information at different stages of the design process. Furthermore, the students' limited maturity hindered their ability to synthesize the collected information and translate it into relevant insights that could be effectively shared among their peers (Swan, et.al. 2020). As a result, during the concept phase, Design and Engineering students appeared to be communicating in different languages, making it challenging for them to establish a shared understanding of the project.

The existence of divergent working cultures between design and engineering students further contributed to the misalignment, particularly in terms of embracing change as an integral part of design development. The design process inherently involves the iterative refinement of ideas, demanding extensive dedication, passion, and a constant drive for improvement (Brown, 2008). However, engineering students may perceive frequent changes as inefficient and frustrating. Unlike design students, engineering students typically do not embrace iterative approaches; instead, they tend to envision a final product from the beginning of the process and work towards achieving that predetermined outcome (Nieusma, D, 2018). This difference in working approach did not align with the evolving concepts developed by design students.

Moreover, a restricted number of students were granted access to simulations depicting the projected building's environmental behaviour, which were shared belatedly in the design phase. This limited availability of simulations hindered design students from effectively assimilating valuable experiential knowledge and impeded their capacity to incorporate essential modifications in response to the simulation outcomes.

Based on these findings, it is crucial to address communication difficulties, workload management, motivation levels, and scheduling coordination to enhance future interdisciplinary collaborations.

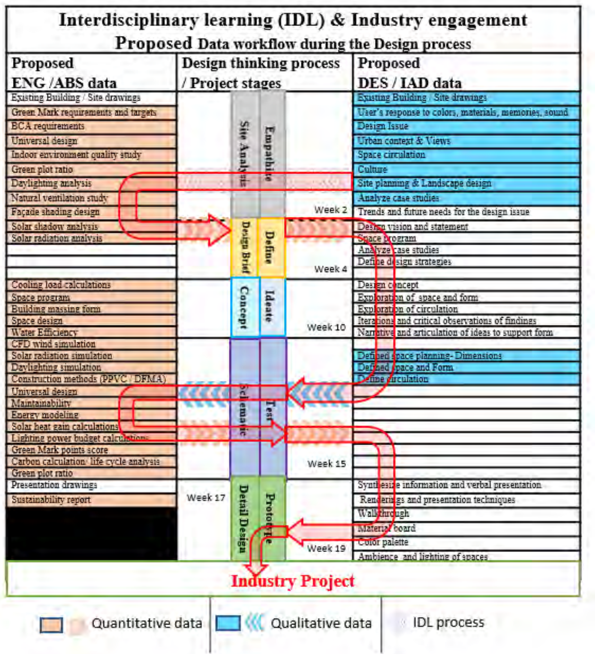
To address these challenges and enhance future collaborations, several recommendations were proposed. An initial ice breaker session is of key relevance to help students from different diplomas to gain the trust needed as a base for collaboration. The kick-off briefing should clearly define the different stages of collaboration throughout the design process, emphasizing the need for a breakdown of critical stages and specific deliverables. Regular joint briefings throughout the semester should be implemented to facilitate progress updates and enable effective feedback exchanges between design and engineering students.

In addition, it is necessary to re-evaluate the timing of sharing key data between design and engineering students. In an industry context, professionals have the ability to synthesize and extract valuable insights from various fields of work, integrating them coherently into the design process. However, as students are still acquiring knowledge and have not yet reached a more advanced phase of analytical reasoning, they may struggle to distil and effectively communicate information (Swan, et.al. 2020). To optimize the outcomes of this collaboration, we have determined that students need sufficient time to acquire new skills, distil information, and share it with their peers in a more coherent manner. This process prepares them for more intensive collaboration in an industry setting.

To facilitate this, we propose that in the initial stages of the design process, students should build upon each other's work. design students can begin with a holistic understanding of the site, while engineering students adopt a more data-oriented perspective. They can exchange their findings during the design brief stage. Design students should then incorporate the input from engineering students into their exploration of concepts and ideas. Engineering students can progressively develop essential skills to support design development, such as Revit modeling and compliance with local green building rating regulations.

During the concept phase, design students should share their concepts and ideas with engineering students, who can utilize them as a foundation for conducting simulations. At the beginning of the Schematic Design phase, engineering students should share their findings on how the proposed buildings interact with environmental elements. Design students should then revise the project to optimize building performance. Throughout the Schematic Design phase, engineering students should collaborate as consultants to enhance the final design. Finally, design students can focus on prototyping and rendering the final design proposals.

By implementing these adjustments and fostering collaborative exchanges at appropriate stages, we aim to enhance the overall effectiveness and integration of Design and Engineering students in the design process.



Conclusions

In summary, the interdisciplinary collaboration between IAD and ABS students in the IDL project has shown both positive outcomes and challenges. The surveys indicate the benefits of embracing diverse perspectives and the skills gained by ABS students in visualization, presentation, and critical analysis. The interviews reveal the positive impact of ABS students' feedback on IAD students' design leadership and idea development, despite challenges such as partner commitment and misalignment in design approaches. The analysis of ABS students' work highlights improvements in integrated understanding and design skills, with collaborative software aiding real-time collaboration (Van den Beemt et al, 2020).

Overall, students acknowledged the importance of interdisciplinary learning in adequately preparing them for the future job market, given its potential to cultivate the requisite adaptability and collaborative disposition. Such an educational approach holds the promise of nurturing versatile professionals capable of thriving in dynamic work environments characterized by complex problem-solving and effective teamwork.

We acknowledge that within the industry, the seamless integration of expertise between designers and engineers is highly recommended. However, in the context of polytechnic academics, where students are in the process of acquiring fundamental skills and exploring their future professional roles, instructors should facilitate a closer guidance in the process of exchange of information. To enhance the IDL experience, it is recommended to adjust the timing of sharing key data, allowing students sufficient time to acquire and distill information before sharing it coherently. The proposed approach suggests design students starting with a holistic understanding while engineering students adopt a data-oriented perspective, exchanging findings during spessific stages of the design process.By implementing these recommendations, future IDL projects can foster effective communication, engagement, and shared understanding between IAD and ABS students, leading to enhanced outcomes and a more enriching educational experienceThis collaborative approach can be replicated for integrative learning across other disciplines of study as well. By engaging with industry partners, this approach facilitates the development of skills that are highly sought after by the industry, thus preparing students to be industry-ready.

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IMPLICATIONS OF PROJECT-BASED LEARNING FOR THE DEVELOPMENT OF AUTONOMOUS TECHNOLOGY

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Abstract

Hong Kong has been promoting the use of electric vehicles (EVs) since early 2010. Based on information from the Hong Kong Environmental Protection Department (EPD), there were 49,005 EVs registered in Hong Kong as of January 2023, which is a significant increase from just 100 in December 2010. However, the growth rate of installed EV chargers and charging stations in Hong Kong lags. Additionally, the lack of charging infrastructure is a major hurdle for EV adoption, particularly in the densely populated urban areas of Hong Kong. Therefore, Hong Kong Vocational Training Council and their industry partner – Totex International Limited have collaborated on a research project aimed at developing an automatic mobile EV charger platform to provide charging services for EVs. Collaboration with institutions and industrial organizations is an important aspect of education and research learning. Furthermore, collaboration between institutions and industry has many benefits, it can provide students with opportunities to work on real-world projects and gain practical skills. Provide students and institutions with networking opportunities and connections that can lead to internship and job opportunities.

The development of autonomous mobile EV chargers has provided opportunities and coached to Higher Diploma students via Project-Based Learning (PBL) program. This research project provided opportunities for students to carry out Final Year Projects and Industrial Attachments with themes relevant to their current study. Engineering students can get involved in different phases of background research, design and development as well as testing and commissioning of the mobile EV charger. The autonomous mobile EV charger platform provides a fully automatic EV charging service to the user. In addition, it can automatically connect through the recharging station to a typical power outlet. The autonomous mobile EV charger was equipped with different types of sensors and it can automatically move to the designated location through Simultaneous Localisation and Mapping (SLAM). Integrating the signal from a 3D camera and lidar, SLAM enables to create of a location map and determines the wanted position. Furthermore, a smartphone app was developed and coupled with IoT hardware to provide real-time monitoring and the current status of the mobile EV charger. This collaboration project emphasizes the provision of PBL opportunities by exposing students early to the world of work, thereby nurturing work-ready graduates. The success of the collaboration project was founded on strong learning and teaching outcomes in Higher Diploma Engineering education touching on key industries driving economic growth in Hong Kong.

Keywords: *Project-based learning (PBL), Technical education, Mobile charging technology, Autonomous, Electric vehicles*

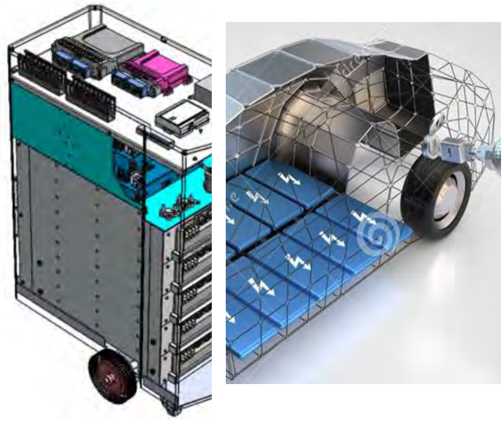
Introduction

In response to global climate change, the Government of the Hong Kong Special Administrative Region announced the Hong Kong Roadmap on Popularisation of Electric Vehicles (EVs) in March 2021. The Roadmap setting out the long-term policy objectives and plans to promote the adoption of electric vehicles in Hong Kong. Expand the EV charging network, promote trials for electric public transport, and promote education and training on EV maintenance to drive the popularisation of EVs and to achieve carbon neutrality before 2050 (The Environment Bureau of the Government of the Hong Kong Special Administrative Region, 2021). According to the Hong Kong Environmental Protection Department (EPD), there were only 100 pure battery EVs in December 2010. The number increased by nearly 500 times to over 49,005 in 2023, representing about 5.3% of the total number of vehicles (Environmental Protection Department of the Government of the Hong Kong Special Administrative Region, 2023). However, the growth rate of installed EV chargers and charging facilities in Hong Kong lags. Based on the information provided by the EPD, there are 3,981 EV chargers for public use including 2,981 medium chargers (≤ 20kW) and 998 quick chargers (> 20kW) installed in Hong Kong and covering all 18 districts in various types of buildings (Environmental Protection Department of the Government of the Hong Kong Special Administrative Region, 2023). The lack of EV charging facilities has become a prime issue to promote EVs. Therefore, Jockey Club Heavy Vehicle Emissions Testing and Research Centre (JCEC) of the Hong Kong Institute of Vocational Education (IVE) Engineering Discipline and their industry partner – Totex International Limited have collaborated on a research project aimed at developing an autonomous mobile EV charger platform to provide a fully automatic charging service for EVs. The project features collaborative teaching and learning where the industry partner and institution supervisors work together to provide opportunities and coached Higher Diploma students via Project-Based Learning (PBL) program.

Vocational Training Council (VTC) was established in February 1982 under the Vocational Training Council Ordinance to provide quality Vocational and Professional Education and Training (VPET) in Hong Kong. VTC encourages teaching and learning with the engagement of industry exposure and in a Project-based environment to encounter complex systems and processes in a competitive environment. In addition, VTC emphasizes the provision of PBL opportunities by exposing students early to the world of work, thereby nurturing work-ready graduates. Since 2021, the industry collaboration PBL project has been established to focus on the development of an automatic EV mobile charger platform. The project team aims to develop an autonomous mobile EV charger to provide a fully automatic EV charging service to EV owners and an opportunity for future smart mobility development in Hong Kong. Furthermore, educating students is one of the core values of the PBL project. It can provide students with board-based engineering knowledge, skills, and value that are essential in the workplace. The PBL project also provides students with an opportunity to apply theoretical knowledge acquired from lectures to the workplace, gain hands-on experience, and encourage students to think outside the box and develop collaboration and communication skills. PBL is designed to be engaging and relevant to students, which can increase their motivation and engagement in the learning process, thus leading students to understand new technologies and practice engineering skills.

Industry Collaboration

Since 2021, the autonomous mobile EV charger PBL project has been established by JCEC and their industry partner – Totex International Limited. The core value of the autonomous mobile EV charger PBL project is to increase students learning outcomes and equip students with professional knowledge and practical skills. The project team consists of professional engineers, teachers, and Higher Diploma students from Mechanical Engineering and Electrical Engineering working together and aims to design and develop a fully automatic EV mobile charger platform for EV charging services (Figure 1). Students are inspired and make use of design thinking to design an innovative and sustainable mobile charger. The mobile EV charger PBL project is enhancing work-based learning by infusing industry collaboration into the core curriculum. Students focused on the works tasks set out by real industry partners in an authentic context, including through real interactions with industry partners, tackling challenges of the projects, and achieving the target progressively in a real-world context. Furthermore, students engaged with this work integrated learning to output designs by using autopilot and machine vision technology, the mobile charger automatically moves to the designated parking space and identifies the position of the vehicle charging socket for charging. When the process of charging is completed, the mobile charger will automatically return to the charging station and recharge its own battery with a 220V/13A AC supply (Figure 2).



a. Mobile EV charging platform

b. Auto plugin to the EV charging socket

Figure 1: Autonomous mobile charging platform for electric vehicles.

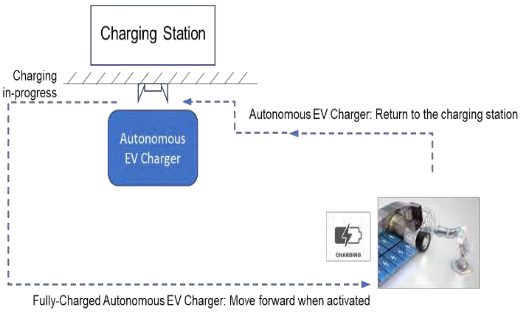


Figure 2: Autonomous mobile EV charger process flow within car park range.

Engagement with industry partners is the critical factor for the success of the PBL project, including the student Industrial Attachments scheme and student Final Year Projects. Also, they are considered a valuable learning experience by academics, students, and employees of the host organizations. First of all, students can apply the knowledge gained from school lectures, tutorials, and laboratories to design and develop the mobile EV charger. Also, students can get the opportunity to work on real-world projects, to gain knowledge and experience through background research, experiment, data analysis, and application of findings to different challenges. The PBL project challenges students to think critically about complex problems and to create possible solutions. This can help students to develop problem-solving skills that are essential for success in the real-world. These experiences also broaden their view in terms of problem-solving, design concepts, and technology application, thus students' self-confidence was highly enhanced. In addition, the PBL project requires students to work in teams, which helps them to develop collaboration and communication skills. This is particularly important in today's workforce, where teamwork and communication are essential. Furthermore, PBL was examined for increasing students' interest, self-confidence, and self-efficacy, which was highly related to the core elements of the autonomous mobile EV charger PBL project such as collaborations in group work, time management, and contextual problems reflecting students' real-world experiences (Baran & Maskan, 2010). PBL project showed positive attitudes toward learning itself, team communication, and collaborative behaviour which were discussed in the literature. Cheung et al. (Cheung, Chow, & Chiu, 2016) evaluated the design thinking process and adopted to the team operation. The process is divided into five stages, including Empathize, define, ideate, prototype, and test. As a result, it is without doubt that the PBL project has positively enhanced students' extra-curricular performances. Students are involved in the industry collaboration project and are motivated to learn and develop theoretical knowledge and hands-on experience. PBL projects also provided an opportunity for students to develop new skills and enhance professional engineering knowledge, which can help them to accommodate different learning style and allows for more personalized learning experiences.

Knowledge transfer

The project team of the autonomous mobile EV charger PBL project was formed by professional engineers, teachers, and Higher Diploma students from Mechanical Engineering and Electrical Engineering working together to develop a fully automatic mobile charger and to impel the knowledge transfer. Students are encouraged to participate in the PBL project because there are many benefits that they can get in the real-life work environment. Students participated in the project with an opportunity to acquire professional competence and practical experience in real-life work environments from industry partners. Furthermore, students have the opportunity to apply theory learned in the classroom, including mechanical engineering and electrical engineering to design and fabricate the mobile EV charger to pursue smart city development in Hong Kong.

To impel the transfer of knowledge, Mechanical Engineering students are mainly responsible for the mechanical design of EV chargers and the mechanism of a robot arm. For the mechanical design of the EV charger, students need to apply their mechanical knowledge gained from the courses “Mechanical Engineering Design” and “Mechanics of Materials”, to consider the mechanical structure and the selection of adequate materials that are appropriate to the application of mobile EV charger. In addition, the mechanism of a robot arm is to position the EV charging plug into the charging socket of the target EV. As shown in Figure 3, the robot arm integrated with machine vision technology and artificial intelligence technology to assist the EV charger to locate and identify the EV’s charging socket position in terms of X, Y, Z, and angle position. Mechanical Engineering students transfer the sensing technology acquired from the course “Automation” to improve the accuracy of the robot arm. The sensing technology including Light Detection and Ranging (LiDAR), Radar, Ultra-sounds and Infra-red was developed and integrated in the mobile EV charger (Figure 4). On the other hand, Electrical Engineering students are responsible for the design of electrical systems and automation navigation systems. Students have the opportunity to apply the battery management system (BMS) technology learned from the course “Electrical Power Systems” for the battery system of EV chargers. The BMS technology managed and monitored the status of the rechargeable battery installed inside the EV charger. Also, the BMS is used to protect the battery from operating outside its safe operating area, monitoring the battery state and balancing between each battery. For the automation navigation system, students applied system navigation knowledge from the course “Control and Automation Systems” for path planning, environment perception, and system control of the EV charger. In addition to the knowledge transfer from the classroom into the EV charger PBL project, VTC encourages students to thrive in various fields and further contribute to the industry and society. Therefore, the project team has coached a number of students in participating in various competitions, including ROBOCON and WorldSkills. The ROBOCON and WorldSkills Competition provided an excellent platform for students over the world to compare notes and exchange their professional skills. Students overcome the challenges and showcase their talents in the international arena.

Figure 3: Robot arm for charging plug insertion.

a. Light Detection and Ranging.

b. Intel Real-sense.

Figure 4: Sensing technologies of the robot arm.

Conclusions

In conclusion, the autonomous mobile EV charger PBL project provided opportunities and coached Higher Diploma students in Mechanical Engineering and Electrical Engineering. The PBL program not only enhances the professional knowledge and technical skills of students but also enriches their employability skills, including teamwork, leadership, presentation and communication skills, time management, and abilities to problem-solve and persuade. In addition, Students have the opportunity to put theory into practice and to be involved in the skills competition to explore their strengths and skills.

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Definitions and Abbreviations

BMS	Battery Management System
EPD	Environmental Protection Department
EV	Electric Vehicle
IVE	Institute of Vocational Education
JCEC	Jockey Club Heavy Vehicle Emissions Testing and Research Centre
LiDAR	Light Detection and Ranging
PBL	Project-Based Learning
SLAM	Simultaneous Localisation and Mapping
VPET	Vocational and Professional Education and Training
VTC	Vocational Training Council

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ENGINEERING EDUCATION IN HONG KONG SECONDARY SCHOOLS – THE APPLIED LEARNING COURSE APPROACH

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Abstract

In Hong Kong, the efficacy of engineering education in secondary schools is always difficult to measure. This is mainly because there are limited engineering-oriented subjects and few teachers with backgrounds in engineering. Engineering education is often infused into the curriculum of secondary schools through science, technology and mathematics (STM) subjects. Students' involvement in engineering related school-based and extracurricular activities are limited. Only a few technical schools in Hong Kong are offering engineering-oriented subjects such as Electronics & Electricity and Technology Fundamentals.

Some previous studies have identified that the lack of engineering education in secondary schools may affect the students' aspiration to become engineers, while some studies have investigated the gap of engineering education at the secondary-tertiary interface. Likewise, many post-industrial societies are facing the same challenges as Hong Kong, which have strong demand for engineers but struggled with the low intake of engineering programmes in higher education and subsequent careers.

This paper responds to the addressed issues of engineering education in Hong Kong secondary schools and performs a practical study of the effectiveness of Applied Learning Courses (ApL), which are introduced to diversify the curriculum of senior secondary students by the Education Bureau of the Hong Kong SAR government. The design of ApL emphasizes the development of fundamental skill set, career-related competencies and generic skills of students, and explore their career aspirations and orientation for lifelong learning.

The overall curriculum design and pedagogy of two selected ApL courses of engineering (electrical & energy engineering and digital construction) will be studied to investigate how the courses can instil engineering knowledge, provide practical 'hands-on' experiences and enhance engineering aspirations among secondary school students.

The study also provides recommendations on improving the design and structure of ApL courses as an approach of effective engineering education in secondary schools.

Keywords: *engineering education, applied learning, curriculum and pedagogy, secondary schools, engineering aspiration*

Introduction

In Hong Kong, engineering education is not included on its own in mainstream secondary curricula. It is typically infused and introduced as part of the science curriculum. In senior secondary level, students can choose to specialize in science and technology, and take courses in mathematics, physics and chemistry, which form the foundation for further studies in engineering.

However, although with a strong exposure to these science, technology and mathematics (STM) subjects, previous studies have found that students do not show significant aspirations to pursue further studies in engineering and to become engineers eventually (Kutnick et al., 2018).

The reform of secondary education in Hong Kong has made the situation even worse, in which the number of technical secondary schools has declined, which means that engineering-oriented subjects are rarely offered in secondary education now.

Secondary school students, however, are always provided with a range of opportunities to acquire knowledge in engineering, such as, school-based extra-curriculum activities, open competitions organized by universities or other organizations, and career talks by professional institutions. How these can enhance the students' aspiration for further studies in engineering and to become engineers, are subject to further investigation.

Aim and Objectives

The aim of this paper is to propose an effective mechanism of engineering education in secondary schools by conducting a practical case study of Applied Learning courses (ApL) in current secondary school curriculum in Hong Kong.

The objectives of this paper are to briefly review the existing problems of engineering education in Hong Kong secondary schools, which affect the aspirations of the students to become engineers; to study the effectiveness of the implementation of ApL in secondary school curriculum; and to provide recommendations on improving the design and structure of ApL courses as an approach of effective engineering education in secondary schools.

Literature Review

Kutnick et al. (2018) conducted a survey among secondary school students on their aspirations to become engineers in Hong Kong, the results showed that the responding students were normally not provided with significant support by the school-based engineering opportunities to contribute to their aspirations. In the study, some contributory factors to aspire the youth to become engineers were also discussed, such as practical activities, encouragement by teachers and parents, motivation to engage in engineering activities, perception of engineers and engineering efficacy.

Other studies on engineering education in secondary schools, such as by Purzer S. & Shelley Mack (2018), Case J. et al. (2013) and Millham, R.et al. (2014), have focused on how the curriculum design, soft skill training and learning style could assist in effective teaching and learning of engineering knowledge. They shared the common view that engineering education can be effectively promoted through science, technology and mathematics (STM) subjects of the curriculum.

Purzer and Shelly (2018) further suggested that the abilities in problem-solving, critical thinking, and creativity are critical in developing engineering education, as well as the importance of integrated learning as the basis of engineering knowledge. Felder (2012) has also stated that traditional lecture-based instruction and monodirectional knowledge sharing is no longer effective in enhancing students’ engineering aspirations.

Moore, T. J. et al. (2014) outlined a framework of engineering education along the learning path of secondary school. The framework was designed to inform the integration of engineering within the secondary school curricula. Some indicators are proposed such as “process of design”, “engineering thinking”, “engineering tools” and “ethics” etc.

The above literature has offered discussion on the design of effective engineering education in secondary schools, through curriculum design, pedagogy, assessment tasks and learning activities. The case studies in the paper will also focus on these areas.

Materials and Methods of Study

The Education Bureau of Hong Kong SAR Government has introduced ApL courses as elective subjects to diversify the senior secondary curriculum. The design of ApL emphasizes the development of fundamental skill set, career-related competencies and generic skills of students, and explore their career aspirations and orientation for lifelong learning. (Education Bureau, 2023)

While there are limited studies evaluating the acheivement of the general objectives of ApL, this study focuses on how ApL can contribute to engineering education in secondary schools. Two ApL courses in engineering, which are entitled “Electrical and Energy Engineering“ and "Digital Construction“ are therefore selected as case studies.

In line with the preivous studies on engineering education in secondary schools, the case studies would also focus on curriculum design, pedagogy, assessment tasks and learning activities.

Case Studies

Two ApL courses operated by Vocational Training Council (VTC) are selected for the case studies, which are entitled “Electrical and Energy Engineering” (EEE) and “Digital Construction” (DC). Among all the ApL courses provided to senior secondary school students, these courses are the two major engineering-related ones.

Secondary schools and their students are offered the opportunities to select ApL courses, which can be embedded into the school curriculum. Classes are usually conducted in school hours or in VTC during weekends.

Apart from normal classroom learning, students are provided with various enigneering-related activities, ranging from company and facilities visits, career talks and guest lectures, etc.

Basic information of the two courses are listed in Table 1.

	EEE	**DC**
No. of Module	3	4
Project based Module	1	1
Contact Hours	180	180
No. of Assessment Task	7	6

Table 1. Basic course information

Curriculum Design

ApL courses are desgined for secondary school students, and hence the purpose is to develop the fundamental skill sets and students' career-related exposure. Essentially, the curriculum design of the courses are guided by five curriculum pillars, namely career-related competencies, foundation skills, thinking skills, people skills and values and attitudes.

In addtion to the five guiding principles of curriculum design, the two courses also have their distinct design parameters.

The EEE course enables students to understand fundamental theories and concepts, develop their generic skills, and address their further studies and career aspirations in the electrical and energy engineering industry. While the DC course aims to provide students with basic knowledge about construction technology.

The learning outcomes of the two courses are demonstrated as:

Electrical and Energy Engineering (EEE)

1. analyse the general profile of the electrical and energy engineering industry, and its latest development;

2. apply the basic principles and techniques of electrical engineering, in particular the knowledge of energy efficiency enhancement to formulate engineering solutions;

3. integrate knowledge and skills in electrical and energy engineering industry, including work ethics and social responsibilities, occupational safety and sustainable development, as well as communication and problem solving skills;

4. interpret the latest development and achievements in the related engineering fields.

Digital Construction (DC)

1. appreciate the general environment of the construction industry;

2. recognise the latest development and achievements in construction technology in the related field;

3. apply the basic principles and techniques of construction technology to formulate solutions;

4. design and implement projects with integration of knowledge and skills in creative thinking, communication skills and problem-solving skills, with due consideration and a basic understanding of the importance of work ethics, safety as well as sustainable development;

5. demonstrate positive values and attitudes towards the construction industry;

6. develop self-understanding for further studies and career development in the related field.

The modules included in the curriculum are showed in below tables.

	Module Title
1	Overview of Electrical and Energy Engineering
2	Utilisation of Electrical Energy
3	Energy Resources and Efficiency

Table 2. List of modules in ApL Electrical and Energy Engineering

	Module Title
1	Understanding Construction Industry
2	Introduction to Construction Technology
3	Application of Construction Software and Equipment
4	Construction Technology Project

Table 3. List of modules in ApL Digital Construciton

Both courses provide an overview of the industries in their first modules, and go on to teach students the fundamental theories and concepts through knoweldge sharing, application and practice. Students are facilitated to integrate the knowledge learned and acquired in completing a study-based project at the end of the course.

The courses are designed to complete in two school years. Throughout the learning journey, students are encouraged to acquire an early understanding of the engineering theories and practice, equipped with soft skills like problem-solving, critical thinking and communication. Most importantly, the strong involvement of students in engineering based activities can effecitvely enhance students' interest and aspirations to pursue further studies in engineering.

Pedagogy

The courses provide a simulated learning environment for students. This is supported with training facilities like electrical project laboratory, electrical installation and repair training workshop, Building Information Modelling (BIM) and geometrics computing laboratory and construction project studio, etc.

Several types of teaching and learning activities are introduced, which are summarized in the table below.

	Type of teaching and learning activity	**Purpose**
1	Classroom teaching	Knowledge sharing and delivery
2	Group discussion and presentation	Reflection of knowledge acquired and sharing of ideas
3	Experiment and workshop	Practical training and application of solutions to practical tasks
4	Project	Knowledge integration and implementation
5	Company and facilities visit	Appreciation of real life practice and know-how

Table 4. Teaching and learning activities

Problem-based learning and active student engagement are purposefully injected in most of the teaching and learning activities. For example, problem-based learning is being implemented in integrated project workshops, in which students are assigned with tasks without a definite solution. Students are encouraged to design, develop and discuss the solutions, by defining and interpreting the problems. The role of the tutor is to facilitate learning by supporting, guiding, and monitoring the learning process.

Students are engaged to actively participate in classes and shared their ideas openly. They are often formed in groups to work like a team to enhance discussion and communication.

Assessments

Both courses include a number of assessment tasks, which are evenly distributed across the course. The types of assessment tasks are listed in the table below.

	Type of assessment task	**Purpose**
1	Test	Examination of knowledge gained
2	Study report	Assessment of information gathering, analysis and writing abilities
3	Presentation	Assessment of communication skills and question-handling abilities
4	Project	Assessment of overall integration of theory and practice, and problem solving skills

Table 5. Assessment Tasks

The assessment tasks are designed to assess students' level of understanding and the attainment of learning outcomes. Feedback on assessment tasks would be given for self-assessing and improvements.

Results and Discussion

Based on the information and findings gathered from the case studies, the effectiveness of the two ApL courses of engineering is evaluated in the following five criteria.

(1) Design Process
(2) Applications of engineering concepts
(3) Problem solving
(4) Teamwork and communication related to engineering
(5) Exposure to engineering environment

These five evaluation criteria are essential in the framework of engineering education and are previously identified by Felder (2012), Moore (2014), Purzer and Shelly (2018).

Design Process

Design process is crucial in defining the issue and formulating solution in engineering tasks. It involves the process of preparation, planning and evaluating the engineering design. In the ApL courses, students are provided with different kinds of engineering tasks which require the design input of students. For example, in EEE course, students are asked to design the electrical energy system. In DC course, students are asked to design new building structure by using BIM software.

Along the design process, students can learn how to identify the issue, generate ideas and plan the implementation process. Each design is subject to review and verification. If the design does not achieve the intended outcome, the process of redesign will follow. It largely resembles the thinking process of an engineer.

Applications of engineering concepts

Throughout the courses, students have many chances to acquire and apply engineering concepts. These range from fundamental engineering knowledge, actual engineering practice, new technology and advancement of the engineering professions, and sharing of practical experiences by professional engineers.

Applications of engineering concepts are usually a combination of knowledge and practice. For example, in DC course, when students are asked to design the site supervision system, they would first identify the existing problems of construction site supervision, and suggest feasible solutions by using digital applications.

Problem solving

Engineers are always ready to tackle problems, and provide solutions in different aspects of engineering professions. The ability of problem solving is essential in engineering eduction. (Jonassen, 2006)

The courses guide students to develop the mindset of problem solving. For example, in EEE course, students are asked to tackle problems related to electrical installation and safety under the client's and statutory requirements. Problem-based learning also facilities students to familiarize with the process and strategies in solving problems.

Teamwork and communication related to engineering

Teamwork is considered a key skill in engineering. A number of attributes such as effective communication, constructive feedback and leadership are widely regarded in successful teamwork. (Chowdhury, 2019)

Students often form into small teams to brainstrom, discuss and analyse the given tasks. In the integrated project module, students can demonstrate the abilities of communication, feedback and leadership through group discussion, report writing and presentation.

Exposure to engineering environment

A number of teaching and learning activities are organized to enhance the learning experiences of students. Among them, some activities allow students to interact with the workplace environment of engineering industry, such as company and facilities visits, career talks and guest lectures.

The courses help students better prepare themselves for further studies and career opportunities in engineering. Outstanding students may have internship opportunities in engineering and construction companies.

Conclusions

This paper proposes and evaluates an effective mechanism to fill the gap of engineering education in secondary schools. Two ApL courses in engineering are studied to investigate their effectiveness to aspire students' interest in engineering, for potential pursuing of further studies and career choices. The curriculum design, pedagogy, assessment tasks and learning activities of the courses are studied.

By matching the information and findings of case studies with five evaluation criteria, the effectiveness of the ApL courses are affirmed.

These are reflected in the following aspects:

1. allows students to develop a basic understanding in engineering and the potential interest into further study and career choice;

2. enables students to learn fundamental theoretical knowledge as well as practical and generic skills in engineering;

3. provides valuable and specific engineering education in secondary curriculum by teaching basic engineering knowledge and a wide range of engineer competencies such as problem solving, application of engineering concenpt, teamwork and communication skills;

4. adopts a variety of pedagogies to motivate students to learn. These includes group discussion and presentation, experiment and workshops, project works, company and facilities visits, simulated assessment tasks.

Recommendations

With regards to the affirmative effect by the ApL approach in engineering education, there are a number of recommendations on improving the design and structure of ApL courses.

1. More interactions between the ApL courses and science, technology and mathematics (STM) subjects. This would help students to connect the knowledge from STM subjects to engineering. For example, in setting assessment tasks of the ApL courses, students can be asked to make use of generic STM knowledge.

2. Support from the engineering industry is essential to bring the most advanced knowledge and practice into the course curriculum. It can be guest lectures, company and facilities visits, scholarships and internship. Professional engineers can also be invited to contribute feedback to curriculum development.

3. Advanced technology in engineering such as artificial intelligence, robotics, internet of things and design software should be largely adopted to arouse the interest of students in engineering.

4. Pedagogies such as technology enhanced learning, project based learning and active student engagement can be strengthened and adopted to the courses.

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Modifying a "Reverse Engineering" Class for the Department of Computer Engineering at KOSEN-KMITL

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Abstract

KOSEN-KMITL has been established in Thailand as the first KOSEN to develop a Japanese-style National Institute of Technology (NIT or KOSEN) abroad. KOSEN-KMITL has introduced the Model Core Curriculum (MCC) and other distinctive educational systems of KOSENs to encourage engineering education.

KOSEN-KMITL has also implemented pioneering initiatives that have not yet been implemented by Japanese KOSEN. One of the pioneering efforts is the distinctive class, 'Reverse Engineering.' This is a course where students disassemble and examine products already in circulation. By disassembling a product and examining its design, students understand the engineering characteristics of the product and learn engineering design by themselves. 'Reverse Engineering' here has a different meaning from reverse engineering in so-called software engineering which is not to recode programming from a sequence of bytes.

This subject is provided to first-year students at KOSEN as part of their introductory education. First, KOSEN-KMITL has established a Mechatronics Engineering Department. At that time, it was reported that the educational impact of this subject has been positive. In the Department of Computer Engineering, the second department established at KOSEN-KMITL, "reverse engineering," which was introduced in the Department of Mechatronics Engineering, was also introduced directly. As a result, student satisfaction was very high. However, there was the problem that some of the analyses were not directly related to computer engineering.

Therefore, this year we will implement reverse engineering related to computer engineering. In this report, we describe in detail what we have implemented and report the evaluations from students through questionnaires. Furthermore, this subject is considered suitable as an effective introduction to universal engineering education. Therefore, it is a useful reference for the introduction of all engineering education, not only KOSEN education. Since it is the result of modification from mechatronics to computers, we believe that it will be helpful in terms of its application to various fields.

Keywords: *Computer science, Reverse Engineering, primary education*

Introduction

KOSEN-KMITL is the first institution in Thailand to adopt the Japanese-style KOSEN school system. It was opened in May 2019 and is under the umbrella of King Mongkut's Institute of Technology Lat Krabang. It fully implements the education system of the Japanese National Institute of Technology (KOSEN) and fosters practical engineers in a five-year course. (e.g., KOSEN)

KOSEN-KMITL students can also participate in internships and training at companies and Japanese KOSEN. KOSEN-KMITL aims to train practical and innovative engineers who support the industries shown in Thailand's industrial policy "Thailand 4.0".

The establishment of KOSEN-KMITL was implemented as a cooperative project between the Japanese and Thai governments. Japan has provided yen loans, and Japanese KOSEN professors are guiding and training local Thai teachers.

KOSEN-KMITL is bringing new possibilities to the Thai education world. It is expected to improve Thailand's industrial technology and contribute to economic growth by adopting the Japanese KOSEN education system.

It is also worth noting that KOSEN-KMITL in Thailand offers a unique type of education that is different from the KOSENs in Japan. One of the key differences is the focus on reverse engineering courses as part of the introductory curriculum. This type of reverse engineering is different from the computer engineering definition, but it is very effective in helping students to understand technology. Komatsu et al. (2020) provide more information on the KOSEN-KMITL reverse engineering program.

In addition to the reverse engineering courses, KOSEN-KMITL also offers a computer engineering department as its second department. The computer engineering department is unique in that it focuses not only on providing Information and Communications Technology (ICT) education to students but also on the use of ICT in education. Kobayashi et al. (2022) report on the impact of COVID-19 on online exams.

Initially, the reverse engineering courses were designed and implemented based on the contents of the mechatronics engineering department, which was the first department to be established. While some degree of success was achieved, students were not motivated to cooperate with the department. Therefore, the theme was changed to be relevant to the computer engineering department in 2020. This change resulted in a significant difference in student evaluations.

This report investigates the evolution of reverse engineering courses at KOSEN-KMITL. The results showed that reverse engineering courses are effective in the introduction of engineering education and that the introduction of more specialized courses can improve the effectiveness of the introduction of engineering education.

Reverse Engineering

Reverse engineering in information engineering is a process of analyzing binary data or executable file format to reproduce and understand the original program.

KOSEN-KMITL has introduced a reverse engineering subject as an introductory subject. The reverse engineering here is different from the general reverse engineering in information engineering. The reverse engineering at KOSEN-KMITL is to understand how a product is created by disassembling the product and to learn the methods of analysis and experiment. This subject is unique and can be very effective as an introductory education for engineering.

Previous reverse engineering at KOSEN-KMITL has been conducted in line with the curriculum of the preceding department, the Mechatronics Engineering Department. The results of the introductory education have been highly evaluated. On the other hand, these themes were not in line with the Computer Engineering Department.

Table 1 shows the topics of reverse engineering in 2021 and 2022. The number of topics in 2021 is small because online classes and other parallel classes were held due to the influence of COVID-19.

Table 1. The theme of Reverse Engineering

AY2021	AY2022
DC Motor	Motor and Coil
Camera	Software and Data
Digital Camera	LAN cable
Display	IR sensor
	Keyboard
	Computer
	AC/DC box (inside a computer)

Student Survey Results and Discussion for Themes

This study surveyed student satisfaction with the reverse engineering course at KOSEN-KMITL in Thailand. The survey was conducted over two years, in 2021 and 2022, with 48 students each year.

The survey asked students "Which projects were interesting to you?" Multiple answers were allowed.

Figure 1 shows the results for 2021.

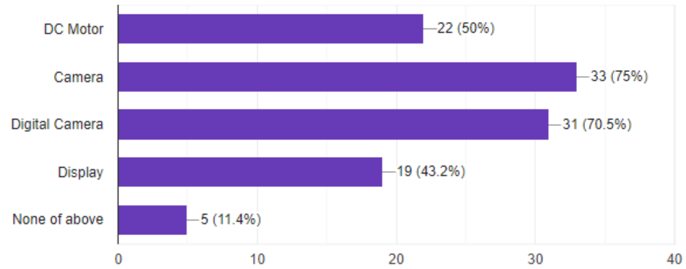

Figure 1 Interest for topics (AY2021)

DC Motor and other topics were found to be interesting to about half of the students, while Camera and Digital Camera were found to be interesting to more than 70% of the students. Display, which is relatively close to computers, was only found to be interesting to 43% of the students.

In the case of Camera and Digital Camera, the actual products were disassembled, and the students were able to see the circuit boards, lenses, and image-processing processors. On the other hand, Display was limited to the analysis of the images on the screen, and the students were not able to touch the circuit boards. It can be inferred that the act of actually opening the product is related to interest. On the other hand, in the case of a DC Motor, even though the magnets and coils that make up the motor were disassembled, only half of the students were interested. We believe that this result is due to the psychological distance between the students' interests in computer engineering and their motivation.

The results for the year 2022 are shown in Figure 2.

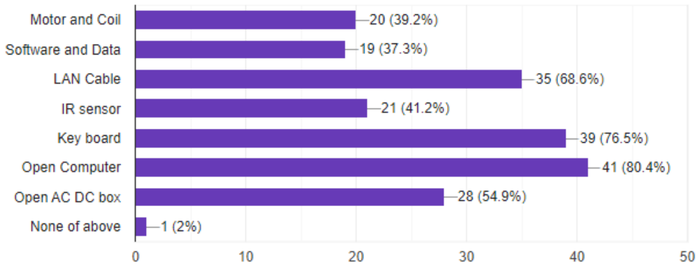

Figure 2 Interest for topics (AY2021)

The interest in LAN cables, computers, and keyboards, all of which are directly related to the Department of Computer Engineering, was very high. This year was characterized by a lower interest in DC motors and other topics compared to the previous year. Whether this indicates the nature of the student population's low interest in subjects other than computer engineering in the first place, or whether the relatively low interest is since the survey was conducted on subjects that are highly related to computer engineering, requires further analysis. In any case, the results confirm the effect that subjects that are highly directly related to computers for computer engineering students can increase student interest.

On the other hand, the evaluation of software that analyzed IR sensors and jpeg files did not interest the students. These may not have attracted the students' interest because the focus was on the analysis using computers and devices, rather than on the actual products themselves.

Student Survey Results and Discussion for Subject

The reverse engineering course itself was also evaluated based on a student questionnaire. The target students are the same as the students in the previous section.

Figures 3 and 4 show the responses of students in the academic years 2021 and 2022, respectively, to the question "On a scale of 1 to 4, do you think this subject relates to computer engineering? The answer shows 1 is Mostly irrelevant, 2 is less relevant, 3 is relevant, and 4 is very relevant.

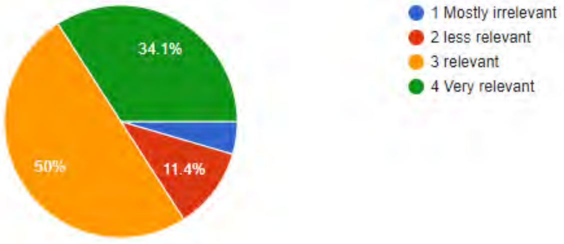

Figure 3 relevant (AY2021)

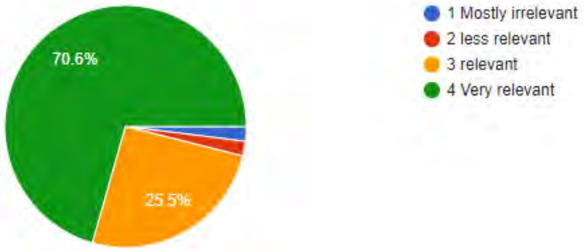

Figure 4 relevant (AY2022)

In 2021, the largest number of students chose 3, while in 2022, more than 70% of the total number of students chose 4. This result is because our course change content made students more aware of the relationship to computer engineering. The Welch's t-test also showed that this mean was significantly different at a significance level of $p<.05$. Thus, the change in subject matter means that students were made more aware of the relevance of the subject to computer engineering.

Figures 5 and 6 show the results of the questionnaire asking about students' interest in the subject itself. Figures 5 and 6 show the results for the years 2021 and 2022, respectively.

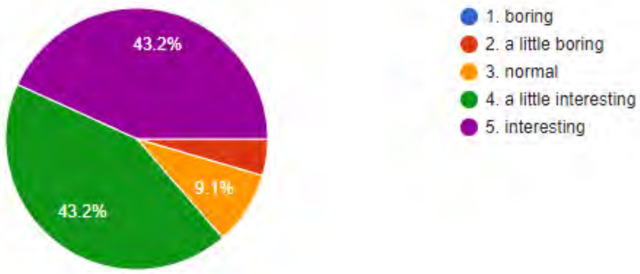

Figure 5 Interest in this subject (AY2021)

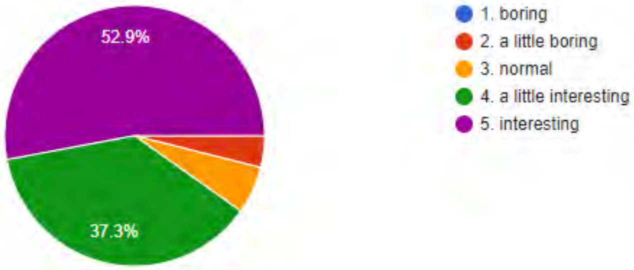

Figure 6 Interest in this subject (AY2022)

From the results, a significance test on the mean did not yield a significant difference. However, the percentage of students who responded "interesting" increased from 43% in AY2021 to nearly 53% in AY2022.

These results indicate that the change to content more closely related to the department's content was effective in attracting student interest.

Thirty AY2021 students responded to the open-ended question of what they would like to learn in such a reverse engineering class.

In the free-text responses, 15 students indicated that they would like to do computer assembly, and 2 students indicated that they would like to copy websites and analyze source code. One student indicated that he did not want to analyze motors.

On the other hand, 36 responses were received from students in AY 2022. Three students indicated that they were satisfied with disassembling the PC. In addition, some opinions showed interest in more detailed computer engineering, such as wanting to disassemble a CPU, disassemble a hardware keyboard, and disassemble a smartphone. There were also opinions such as wanting to know what is inside various software.

Although not simply comparable, we believe that these results confirm that our aims have been realized in the following respects. First, the students are interested in education that is appropriate to their department, as more than half of the active students who responded in

AY2021 wanted to learn more about subjects closer to their majors in this course. For students in AY2022, the results indicate that the introductory education has been successful in creating a desire to learn more about the subject.

Of course, we cannot ignore the influence of the difference in learning opportunities and learning together with friends due to changes in the social environment, such as COVID-19. However, we believe that the fact that many students developed a desire to reverse engineer computers and were motivated to actively learn about their majors was very effective as an introductory education.

Conclusions

Reverse engineering is one of the unique introductory courses at KOSEN-KMITL. In this report, we describe the results of the modification of the curriculum of reverse engineering, which was not designed for the Department of Computer Engineering, to a curriculum.

The questionnaire survey showed that students understood the relevance of the subject to computer engineering and that they were more aware of the relevance of the subject than in the previous year, with a significant difference at the $p<.05$ level of significance. Regarding interest in the subject, about 53% of the students were also able to develop the most interest in the subject.

These results suggest that when students are made aware of the relationship between their department and a subject, their interest in that subject increases. This result has positive implications not only for computer engineering but also for engineering education in general. Particularly concerning introductory education, attracting interest is very important for the long years leading up to graduation. Therefore, we expect that our approach will be very effective for engineering in general.

In the future, we would like to explore introductory education for each department, and design and plan classes that will generate interest in the subject among students.

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ENGINEERING AND BUSINESS EDUCATION IS IN THE WHIRLWIND OF REFORMS

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Abstract

During the past ten years engineering and business education and research at the Turku University of Applied Sciences have changed remarkable. This study uses qualitative methods and describes a case study on the actions taken at the Turku University of Applied Sciences in the field of engineering and business for curricula reform and faculty development. The main research question is "How engineering and business education has been steered with curricula reforms during the faculty development process?".

Early 2010 our university had three faculties offering engineering and business education, and we had a pedagogical framework called Innovation pedagogy. The faculty of Engineering, Environment and Business (EEB) was one of the key developers and implementers of this pedagogy. At the same time the faculty of Telecommunications and e-Business (TEB) focused on implementing the international CDIO framework. The third engineering faculty Life Sciences and Business (LIB) followed university's general pedagogical framework. In addition, there were faculty for Arts and two faculties for health and well-being.

In 2013 two of these engineering and business faculties (TEB and LIB) where merged to a new faculty of Business, ICT and Chemical Engineering (BIC) and first major curricula reform was introduced. The reform leaned on the elements in the CDIO approach bringing for example Introductory and Capstone courses into the curricula.

In 2018 two remaining engineering and business faculties (EEB and BIC) were merged into the current format of Faculty of Engineering and Business. At the same time, second major curricula reform was implemented. It combined the main elements of Innovation Pedagogy and CDIO and created a common framework for all our bachelor programs in engineering and business.

At the end of 2022 third curricula reform was started with the aim of new curricula for autumn 2024. This reform had three main aims: 1) Professional core in focus, 2) Strengthen the quality of education and improve completion and 3) Personnel well-being.

Along with the mergers and curricula reforms the operational questions have been solved too as during this journey of ten years the number of students has increased heavily, the portfolio of degree programs has evolved, applied research has grown, and continuous learning has a bigger role. This paper describes how engineering and business activities have developed and how we have responded to the ever-growing demands and global challenges.

Keywords: *Curricula reform, CDIO, Innovation pedagogy, faculty merger, case study*

Introduction

The Finnish higher education system consists of the universities and universities of applied sciences. A total of 13 universities and 22 universities of applied sciences operates in the Ministry of Education and Culture's administrative branch. Universities focus on scientific research and education based on it. Universities of applied sciences, on the other hand, offer a pragmatic education that responds to working life needs. The main emphasis of research, development and innovation at the universities of applied sciences is on applied research and development. (Ministry of Education and Culture, 2023) Turku University of Applied Sciences (TUAS) is a higher education institution of 12,000 experts, researchers, students, faculty members and teaching professionals located in Southwest Finland. TUAS is a significant regional actor with close ties to businesses and municipalities in Southwest Finland. TUAS is the fourth largest technical university in Finland. (Turku University of Applied Sciences, 2023) The degree programmes of TUAS cover all major fields of engineering and business. The emphasis of TUAS education is in Bachelor degrees, where the engineering degree is four years and the business degree is three and half years. In addition, we offer Master degree as part-time studying while students work at the same time and studies are strongly connected with their work.

TUAS has a long tradition in pedagogical development. TUAS was the first Finnish higher education institute to join international CDIO initiative already in 2007. The CDIO approach aims at educating students with deeper working knowledge of the technical fundamentals and educating engineers that are capable of leading the creation and operation of new products and systems (CDIO, 2023a). The other major pedagogical framework we have developed by ourselves: Innovation Pedagogy. The core of innovation pedagogy emphasizes interactive dialogue between the educational organization, students, and surrounding working life and society. The core idea in innovation pedagogy is to bridge the gap between the educational context and working life.

(Kettunen, 2011) Luckily both CDIO and Innovation pedagogy have similar goals and aims, and they complement each other (T. Penttilä & Kontio, 2014; Taru Penttilä, Kontio, Kairisto-Mertanen, & Mertanen, 2014).

Early 2010 TUAS had three faculties offering engineering and business education. The faculty of Engineering, Environment and Business (EEB) was one of the key developers and implementers of Innovation pedagogy. At the same time the faculty of Telecommunications and e-Business (TEB) focused on implementing the international CDIO framework. The third engineering faculty Life Sciences and Business (LIB) followed university's general pedagogical framework. In addition, there were faculty for Arts and two faculties for health and well-being. Since then, the engineering and business education and research has had three major reforms during the last decade. The reforms have included both organizational and pedagogical changes. Along with the mergers and curricula reforms the operational questions have been solved too as during this journey of ten years the number of students has increased heavily, the portfolio of degree programs has evolved, applied research has grown, and continuous learning has a bigger role. The changes happened in TUAS can be reflected on the five general pathways of universities presented by Clark (1998). First, the strengthened steering core is needed because the complexity of universities has increased, and the pace of change has accelerated. Thus, there is a need for a greater managerial capacity. Second, the expanded developmental periphery refers to the need to reach across the old university boundaries, link with outside organizations and groups and build outreach structures such as research centres. Third, the diversified funding base becomes essential when the governmental funding base is hardly increasing. Fourth, the stimulated academic heartland emphasizes the need to achieve changes in the departmental level and turn them to entrepreneurial units reaching outside with new programs and relationship and promoting new income sources. Fifth, the integrated entrepreneurial culture refers to the work culture that embraces change and creates ground for new practices and innovations.

This paper describes how engineering and business activities have developed and how we have responded to the ever-growing demands and global challenges and how these changes reflect with the general pathways Clark (1998) presented.

Research

This study uses qualitative methods and describes a case study on the actions taken at the Turku University of Applied Sciences in the field of engineering and business for curricula reform and faculty development. The main research question of this study is "*How engineering and business education has been steered with curricula reforms during the faculty development process?*".

A case study is a research method aiming for an in-depth analysis of a particular phenomenon (Cavaye, 1996). Methodologically this is a descriptive case study research. A descriptive case study presents a complete description of a phenomenon within its context (Yin, 2002). The unit of analysis is engineering and business education, RDI and organizational context at TUAS. This is studied through three development phases/cases:

- Case 1: Focus on CDIO
- Case 2: Common framework
- Case 3: Professional core.

In a typical case study research multiple data collection methods are used (Yin, 1994). In this research, data was mainly gathered from the existing documentation and archival records of the author from 2008 to this date. The data covered the memos of university's management board, memos and other materials of faculty's management team and personnel meeting materials. The author has been an active participant of all the three cases, but in this study the analysis will be done in a role of outside observer reflecting the things that have happened and done. The three cases represent changes happened in 2013, 2018 and 2022.

Case 1 – Focus on CDIO

Turku University of Applied Sciences reorganized themselves in 2004 when the number of faculties were decreased from ten to six. The main driver for this was to strengthen and clarify the managerial capacity to respond to the increased complexity of university operating environment. In 2013 it was time to take the next step when it was decided that TUAS would start as a limited company at the beginning of 2014. Before that change the university was part of the City of Turku. At the same time in 2014, the government funding dropped 14%. Both changes were initiated by the Ministry of Education. The dramatic decrease of funding forced university to take actions to balance the financials. At TUAS, 20 people were discharged and 27 were shifted to part-time employment contracts.

At the same time, it was also decided that two engineering and business faculties (TEB and LIB) will merge to a new faculty of Business, ICT and Chemical Engineering (BIC) starting at the beginning of 2014. The new faculty was a good example of a truly multidisciplinary organisation with around 3000 students and around 170 faculty members including teachers, researchers, project workers and all others. In practice, two former faculties worked as one faculty, but major organizational changes were delayed until the beginning of 2015. This change decreased the number of schools and defined stronger head of school positions to take responsibility of education and RDI within broader areas. Before the merger, we had research programmes led by Heads of RDI and these programmes included research groups. The merger stopped the research programmes and focus was placed in research groups. At the same time number of research group dropped from 12 to 7 and each remaining group had larger and more viable RDI focus.

One driver to merge the mentioned faculties was to strengthen the connection to local industries and provide broader connection point to the economy. The change meant that the number of superiors dropped from 15 to 5. These positions were full-time superior positions, but they had degree programme leaders and research group leaders to support daily operations although these were not superiors rather more like team leaders.

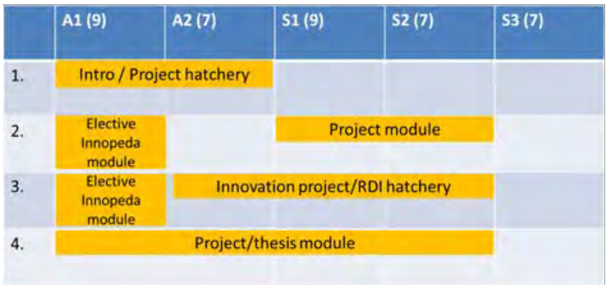
Table 1. Comparison of faculties

	TEB	**LIB**	**BIC**
Dean	1	1	1
Schools & Head of Education	5	4	
Head of RDI	1	1	
Head of continuing education	1	1	
Schools & Head of Education and Research			4
Total	**8**	**7**	**5**

At education there was an urgent need to move away from a fragmented curriculum towards learning that is based on problems and phenomena. There were two guiding tools in this reform: Innovation pedagogy and CDIO. However, CDIO approach was the most dominant guiding principle that was used in this reform. The reform put together two faculties that didn't have any common elements in their curricula and the other one had already used CDIO approach while the other has mostly followed Innovation pedagogy. Thus, the reform started with a fundamental assessment of the curriculum-wide goals and involved a high-level re-alignment of the entire curriculum structure in the whole faculty. The reform work involved two Bachelor of Engineering programs (Information Technology and Chemical) and four Bachelor of Business Administration programs (Business, International Business, Library and information services and Business information systems).

The curricula reform implemented several principles to our curricula:

- Curricula is based on relatively large modules (15 ECTS) compared to the individual courses with relatively low number of credits.
- Study year is divided in two semesters and five periods (Autumn: 9 + 7 weeks, Spring: 9 + 7 + 7 weeks). This rescheduling balanced the workload of students and staff better between shorter autumn and longer spring semester.
- Introduction to – courses in first semester: This idea is directly from CDIO Standard 4 and this course should provide framework for the studies and engages students from the beginning of studies to his/her own study field. The implementation of these courses follows CDIO Standard 8. Active Learning (CDIO, 2023b).
- Multi-disciplinary innovation project (15 ECTS) in third year of studies for all faculty students. The project assignments are mainly from industry and the projects cover the whole life cycle of a product development process from an initial idea phase to closing the project. The implementation of this course follows CDIO Standard 5. Design-Implement Experiences.
- Elective modules included in the beginning of second and third year (15 ECTS each). This answered to the requirements of TUAS university degree regulations at that time. Furthermore, it supported the idea of having broader knowledge of the field than just deep knowledge on your own field.



	A1 (9)	A2 (7)	S1 (9)	S2 (7)	S3 (7)
1.	Intro / Project hatchery				
2.	Elective Innopeda module		Project module		
3.	Elective Innopeda module	Innovation project/RDI hatchery			
4.	Project/thesis module				

Figure 1. Common curricula framework for BIC.

Altogether the CDIO approach was widely utilized in the curricula reform work supported with workshops organized by external experts. The whole curricula reform case is described in Kontio (2014).

Case 2 – Common framework

Since 2014 TUAS had four faculties: Faculty of Engineering, Environment and Business (EEB), Faculty of Business, ICT and Chemical Engineering (BIC), Faculty of Health and Wellbeing and Art Academy. In 2015 work for creating a new university strategy started. The strategy had four main areas of which one focused especially on the engineering and business field. The title of this area was "Future technological innovation university". This basically implicated that TUAS need to build new faculty that takes care of all professional engineering and business education and applied research to support and improve the industry and well-being in Southwest Finland. It also defined four broad spearheads to focus university activities: Maritime cluster, circular economy, sales, and digitalization. The introduction of the new strategy and this idea of new unmentioned faculty started active work on necessary development actions on education and research. A concept of "Engineering excellence in action" was introduced and connected to the existing pedagogical and practical approaches of Innovation pedagogy and CDIO.

Four different viewpoints were identified for the areas of improvement:

- The structures of programmes: flexible curricula, active learning with projects
- New learner: supporting intrinsic motivation, provide individual learning paths
- New teacher: moving towards coaching, connections to industry
- New culture: raise the level of requirements, strengthen and renew learning and study culture.

This development work was influenced strongly by the work of Goldberg and Somerville (2014) and the study provided by Graham (2012). Graham (2012) reported that to achieve long-term change in engineering education a) typically 20% of curriculum, or less, is non-traditional, but curriculum is strongly interconnected, with multiple dependencies, where faculty and students have a clear understanding about the education as a whole and b) faculty should not be forced to deliver non-traditional courses but are aware of the positive impact they have on students.

During 2015 until 2017 the programs in the BIC faculty constantly improved their curricula according to the existing general common curricula structure and considered pedagogical emphasis provided in Innovation Pedagogy and CDIO. Along this development work in the BIC faculty a deeper collaboration started with the EEB faculty.

In the summer of 2017 work for new administrative structure was started. Now it was clearly stated that we would have only on engineering and business faculty. The main idea was to further enhance the integration of education and research, strengthen networking in our region and strengthen relevance to regional industry and their needs. This new organization started at the beginning of 2018. Two remaining engineering and business faculties (EEB and BIC) were merged into the Faculty of Engineering and Business (EB). The faculty had 310 experts and about 5800 students, 20 research groups. The merger was planned and worked during 2017 and 2018. In 2018, the organisational structures stayed but the faculty was managed as one entity and school and their leaders started working for the new faculty.

The reorganized faculty started at the beginning of 2019 with seven schools and seven Heads of Education and Research. The research groups were reorganized too, and the number of research groups decreased from 20 to 14 at the beginning of 2019.

Early 2018 the new faculty agreed common curricula principles that simplified the guidelines the two earlier faculties had jointly. Three of the principles defined mandatory courses to all curricula: Project hatchery 5 cr (first autumn), Introduction to your own study field – module (first year), Innovation project – 10cr + 5 cr (third year). Furthermore, it was agreed that we will focus on additional student guidance, take care of special competence needs and organize 2nd and 3rd years in module days. At the same time, we dropped the idea of having five period rather we just have autumn and spring semesters. Furthermore, the provision of faculty wide elective modules was stopped, and we will encourage students to choose free elective studies from the normal courses offered by other programmes.

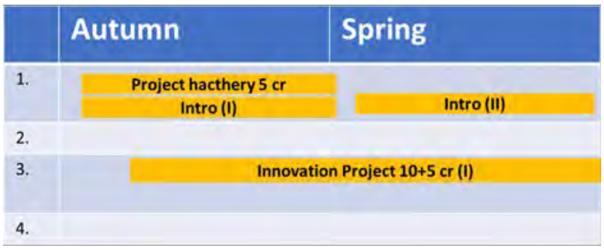


Figure 2. Simplified curricula framework for EB.

Once the common framework was defined, we wanted to involve whole faculty personnel in a series of workshops to think how we can do better in education and research. This process is well documented in Kontio (2018). The workshops identified several possible areas where we could do better:

- Use of time and resourcing: how to create a feeling of increased time and resource – decrease options and more standardized study modules?
- Integration of research and teaching&learning activities should be further strengthened already in the project application phase
- Standards and student engagement: Requirement level and mastering studies from the beginning – learning to learn the UAS way
- Create opportunities and places to share good practices
- Everyone can think whether I'm doing my best with the given conditions
- Co-teaching is an accepted way of teaching&learning – could we use it more?
- Keep competence-based approach at the centre of teaching and learning
- Student guidance: we need to recognize when early intervention is needed, and we need to act like superheroes capable of supporting students as well as possible.

These themes have been in constant discussion on our daily work and they have given us guidelines to remember in our daily activities since 2018 reform.

Case 3 – Professional core

Early 2022 the Board of the University decided that the university strategy needs updates and work to define new strategy was started. New strategy work started since we had reached many of the key goals in advance such as the implementation of "Future technological innovation university". The strategy work partly activated another curricula reform at the end of 2022 with the aim of new curricula for autumn 2024. This reform had three main aims: 1) Professional core in focus, 2) Strengthen the quality of education and improve completion and 3) Personnel well-being. With the first aim, we wanted to highlight more the professional core of our programs and to reflect our new strategy as well as megatrends and national level general competences. Furthermore, we challenged all programs to really strengthen the quality of education and find reasoned solutions to learning. The key competences of each program should be emphasized and critically reflect the number of modules/courses/topics included in the curricula. We also encouraged programs to find joint modules/courses and standardize courses common to all. We wanted to improve and support personnel well-being with enhancing cooperation, get rid of fragmented work duties and give personnel opportunity to focus and strengthen their competences.

We also defined the general principles for the new curricula. The curricula should make a wholeness and show how students grow professionally within their studies. Overall, the curricula should be a more coherent entity instead of a collection of courses. The curricula will have four project entities:

- 1st year: Introduction to your own study field (10-15 ECTS)
- 2nd year: updated project hatchery focusing in Unesco's sustainable development goals (3 ECTS).
- 3rd: Capstone Innovation project (10 ECTS)
- 4th: RDI-project (5-20 ECTS).

Second- and third-year projects are multidisciplinary and all students participate. First and fourth year projects are program specific activities.

In 2020, we concentrated our activities on one campus and we introduced new campus building with up-to-date laboratories and research facilities. With the curricula reform we wanted to take full advantage of this infrastructure. Furthermore, active learning should play even a bigger role in our teaching and learning than earlier. All these changes require that our personnel are competent and have the latest knowledge available. Therefore, our personnel should join RDI-activities and acquire the latest knowledge and know-how. In addition, we identified needs to support digital competences, language skills and multicultural competences. Finally, the curricula must fulfil the idea of constructive alignment (Biggs, 1996) where learning outcomes, teaching and learning activities and assessment for a mutually supportive whole.

Together with the curricula reform we decided to introduce three new fully English engineering degree programs in addition to the existing Degree programme in Information and Communications Technology and Degree programme in Business Administration. Autumn 2023 will start Bachelor of Engineering programs in Industrial Management and Engineering, Energy and Environmental Engineering and in the autumn of 2024 Degree program in Mechanical Engineering.

At the beginning of 2023, the Faculty of Engineering and Business had grown remarkable from the starting phase in 2018. The number of students is now almost 8000 and we have over 350 staff members within the seven schools. Thus, we initiated an organizational change as well early 2023. We decided to introduce a new school called the School of Common Studies. It will take responsibility maths, physics, languages, and our common project courses (project hatchery and capstone innovation project) plus tutoring in the beginning.

Discussion

The study showed three major phases in the development of engineering and business education and other activities at the Turku University of Applied Sciences. Alongside these phases, the faculty structure has had two rounds of mergers as shown in figure 3.

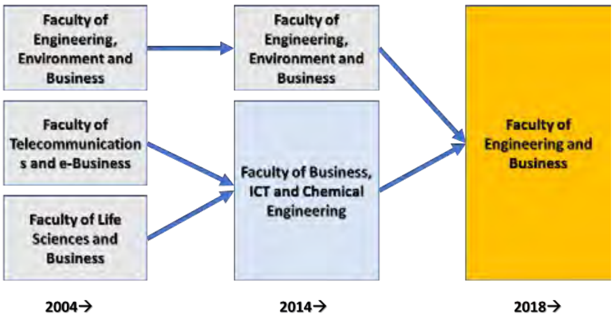


Figure 3. Faculty mergers at TUAS..

Clark (1998) presented five different pathways for universities when transforming themselves towards enterprising universities which actively seek to move away from close governmental regulation and sector standardization. At TUAS the first steps were taken already in 2004 when number of the faculties were cut to six and managerial capacity was stregthened. Already in 2004, we saw the need to strengthen our RDI-activities and new positions in RDI were introduced as Head of RDI at faculty level together with RDI manager at university level. Since then, the RDI outreach has expanded and external funding has increased heavily. In 2014 we stopped the research programmes and placed our RDI focus on research groups. At the same time, the provision of continuing education and industry personnel trainings were active part of TUAS. In practice, it was time of expanding peripheral development in Clark's terms. 2014 was also the time when governmental funding decreased 14% and our university became a limited company. All these changes can be reflected on our attempt to diversify our funding base and that work is still continuing. Introduction of English degree programmes is a good example on that as degree students coming outside European Union have tuition fee instead of free education for Finnish and EU students.

Our change in 2018 was another typical example of Clark's pathway definitions. The merger of two faculties made each school more focused and coherent units giving them more power to solutions in education and RDI. The common curricula guideline only defined 15 ECTS exactly and several general guidelines. The research groups were strongly integrated into education. The school financials were monitored as whole instead of each element separately. The schools started acting like entrepreneurial units that had a lot of freedom together with responsibilities too. This period reflects well with Clark's definition of the stimulated academic heartland.

The latest reform at TUAS has elements echoing the fifth pathway: the integrated entrepreneurial culture. It is the very first time that the whole curricula reform is projected as a faculty wide exercise. All schools have a common project group for agreeing and finding common structures and principles on curricula. Schools are developing and implementing elements that embrace change such as faculty wide math tests at the beginning of studies and faculty wide first math course in all our engineering programs. Furthermore, the introduction of a new school taking care of certain element in all other schools and creation of a matrix organisation is a new cultural agreement in the Faculty of Engineering and Business.

Conclusions

This paper has presented a longitudinal case study on engineering and business education, RDI and organizational context at the Turku University of Applied Sciences. The paper presented three development phases and described the steps and paths between the phases.

The study showed that organizational changes support and facilitate steering of reforms in education and curricula. The organizational changes and mergers justify the inspection of curricula and how education is done in general. The mergers have also given good opportunities to strengthen managerial structures by making larger units with larger responsibilities and thus creating more space to operate in.

Reflecting back to this period of over 10 years show that Turku University of Applied Sciences has succeeded in merging their engineering and business faculties. The success is proven by the increased number of students and graduates, more than doubled external research funding, and shared goals and ways of working.

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A case study of the guidance for experiment with “Interactive Experiment Notebook” (IV) ― Utilization of Prediction & Verification Sheets and Trial of Remote Experiment―

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Abstract

In science and engineering education, many student experiments are conducted to confirm laws and learning techniques. However, because of this, student experiments have a "passive" character for students. Students are evaluated based on the results of their reports, but the ``systematic guidance of lab notebooks", which is the basis of their reports, is often not implemented. However, it is important from the point of view of the "recording and thinking tool" that students write notes on the spot during experiments. Until now, we have been aiming to cultivate literacy accompanied by logical thinking and problem awareness through notebook instruction. In other words, we have tried to convert student experiments, which have a passive character, into an active character through laboratory notebook guidance, and have presented the results several times. Therefore, this time, we made the following two new attempts in the electrical and electronic experiment subjects for senior students of the Department of Electrical and Electronic Engineering. In other words, 1) The use of a preliminary study sheet on experiment content and safety, and 2) A remote experiment attempt to respond to the Covid-19 disaster. In 1), before the experiment, the students consider the contents described below and write them down on the sheet. That is, "specifically, possible troubles (especially safety) that may occur in experiments and how to deal with those troubles" and "matters to be noted when conducting experiments and countermeasures against them, etc." Each student then brings the completed sheet to the experimental team. Then, based on each other's sheets, the experiment team members complete the "experiment content and safety preliminary review sheet" as a team. During the experiment, the students will post this sheet and share information. Through this trial, we will develop the ability to perceive and consider various possibilities in advance and respond to them. Regarding 2), the student experiment team will be divided into two groups, one of which will experiment, and the other will remotely instruct the experiment and analyse the data. The two groups will use the remote tool "Microsoft teams". This will ensure as much social distancing as possible. At the same time, we aim to cultivate accurate communication skills, such as conveying one's thoughts to others, which is considered necessary for various tasks such as remote work, which is expected to increase in the future.

Keywords: *New Era with COVID-19, Interactive Experiment Notebook, Student Experiment, Science Literacy, Active Learning*

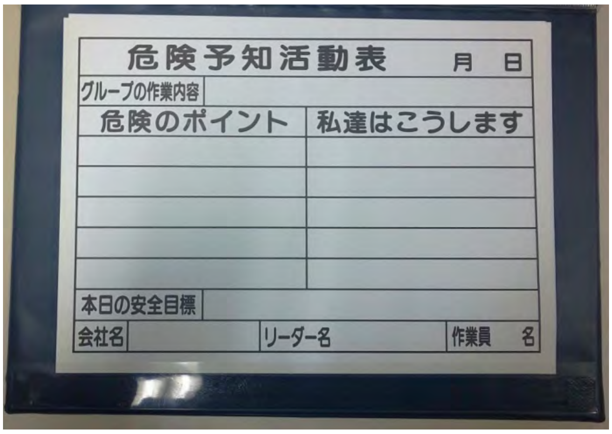
Introduction

In the field of science and engineering education, many experiments are conducted by students in order to understand laws and acquire related techniques. In that sense, student experiments are largely training in nature, and fundamentally have a passive nature. Students' evaluation of experimental subjects is mainly based on the reports submitted by the students, but no systematic guidance is provided on the lab notes that form the basis of the reports. However, for science and engineering students, it is important to write in the experiment notebook, which is the basis of the report. However, despite its importance, there has been no systematic guidance on laboratory notebooks. Therefore, we have been conducting research on systematic experiment note-taking instruction in science and engineering education (Koshiji, 2015, 2016 and 2017). Now, this time, we tried the following two points. That is, (1) Adoption of Risk Prediction Sheet (KY-Sheet) for student experiments, (2) Trials of remote experiments and utilization of the accompanying electronic bulletin board. These matters will be described in detail below..

Adoption of Risk Prediction Sheet (KY-Sheet)

In modern society, in recent years, various unexpected things have happened in which conventional experience and know-how do not apply. Specifically, in Japan, the 2011 Great East Japan Earthquake, the nuclear power plant accident induced by the earthquake, and the frequent torrential rain disasters correspond to this. Globally, the global spread of COVID-19 infection and the spread of Conversational AI are thought to correspond to this. In such an unpredictable era, engineers need to rationally understand various elements on a fact-based basis, have an awareness of the issues, anticipate responses, and work on the issues. Therefore, engineers in the future will have to tackle problems with a PBL perspective and response more than ever before. PBL education and active learning have been advocated as training for this purpose. Through these, cognitive, ethical and social abilities, culture, knowledge, experience, etc. are nurtured. However, in order to do so, it is necessary to prepare the optimal environment for carrying out group work, and furthermore, it is necessary to carefully select the subjects for these efforts. On the other hand, in our approach, we were able to change the passive student experiment into a place for PBL education and active learning just by changing the viewpoint 180 degrees while maintaining the basics of conventional student experiments. The specific contents are described below.

Currently, at construction sites in Japan, “KY-Boards” (or “KY-Sheets”) are used to clarify the types of dangers that can be expected in the work to be done on the spot and how to deal with them. Here, KY is an acronym for “Kiken Yochi (japanease) “= “Risk prediction”. Figure1 shows the appearance and details of the KY board that is actually used in Japanese factories and construction sites.



危険予知活動表　月　日

グループの作業内容

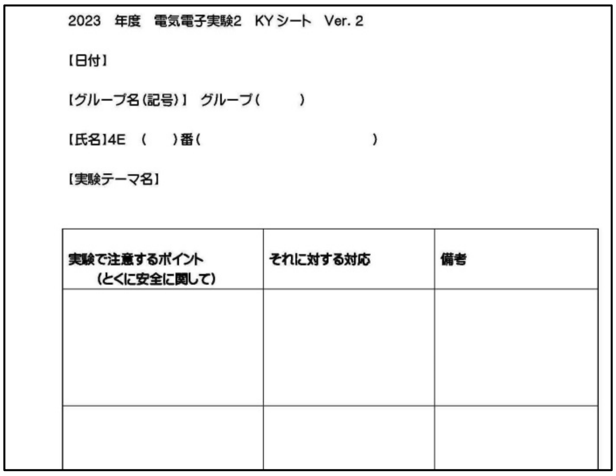
危険のポイント	私達はこうします

本日の安全目標

会社名　リーダー名　作業員　名

Figure 1 KY-Sheet (Risk Prediction Sheet) The sheet contains items such as the date, work content, dangerous items and countermeasures, safety goals for the day, leader name, number of people working, etc.

This time, we adopted the format of this KY-Sheet into the student experiment. Specifically, before conducting experiments, students should read the experiment manuals and reference materials as necessary to understand the content. After that, the students will pick up matters to be kept in mind or conscious of during the experiment (mainly safety aspects, including how to proceed), think about countermeasures by themselves, and write these on the KY sheet (Figure2). Therefore, the format adopted this time includes a wider range of content than the conventional KY sheet, which focused on safety. Then, the experiment leader summarizes the contents of the sheet individually filled in by the experiment team members as the team's opinion, creates a "team KY sheet"(Figure3), and displays it during the experiment. As a result, students could conduct experiments safely, and at the same time, students' experiments, which had a passive nature, could be tackled as a place for active learning.



2023　年度　電気電子実験2　KYシート　Ver. 2

【日付】

【グループ名(記号)】 グループ(　　)

【氏名】4E　(　　)番(　　　　　　)

【実験テーマ名】

実験で注意するポイント (とくに安全に関して)	それに対する対応	備考

Figure 2 KY sheet for individual students (partial excerpt) The sheet contains the date, group name, student name, experiment theme name, points to note in the experiment, response to it, and remarks.

2023年度　電気電子実験2　KYシート　Ver. 2　チーム用　【日付】西暦　　年　月　日(　曜日)　安全や危険対応については赤字で

【チーム名／学生氏名全部】 チーム(　　)

【実験テーマ名】

実験で注意するポイント	それに対する必要とされる対応	備考

Figure 3 KY sheet for team (partial excerpt) This sheet contains the same items as shown in Figure 2.

Trial of Remote-style Student Experiment

Since 2019, the COVID-19 pandemic has started around the world. In Japan, the first infected person was reported in 2020. Since then, there have been several peaks of infection in Japan, and the lives of the Japanese people have been greatly affected. “Avoid the Three Cs (Closed spaces with poor ventilation, Crowded places with many people nearby, Close-contact setting such as close-range conversations) “were advocated in Japan as well as overseas. And social distance was advocated as one of the means. Now, in the electrical and electronic experiments that are the subject of this research, students gather in a small laboratory and use various devices at the same time, so crowding, close contact, and contact between students is inevitable. Therefore, in order to keep a certain social distance, we tried a remote experiment. The contents are as follows.

An experimental group consisting of four students is divided into two groups. The first group will be the "instruction analysis group", which conducts experiments and analyzes in the HR classroom, which is separate from the laboratory. The second group will be called the “experimental group,” which will actually conduct experiments in the laboratory. Then, the two teams will communicate with each other through the remote meeting tool, Microsoft Teams, and carry out the experiments while cooperating with each other (Figure 4).

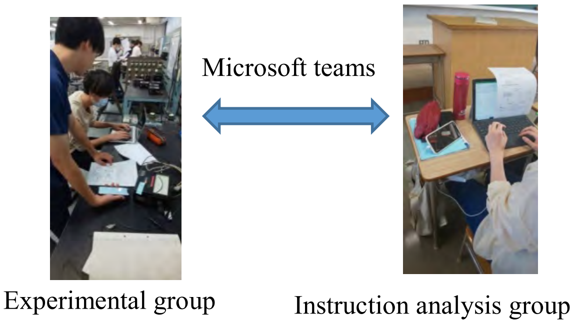
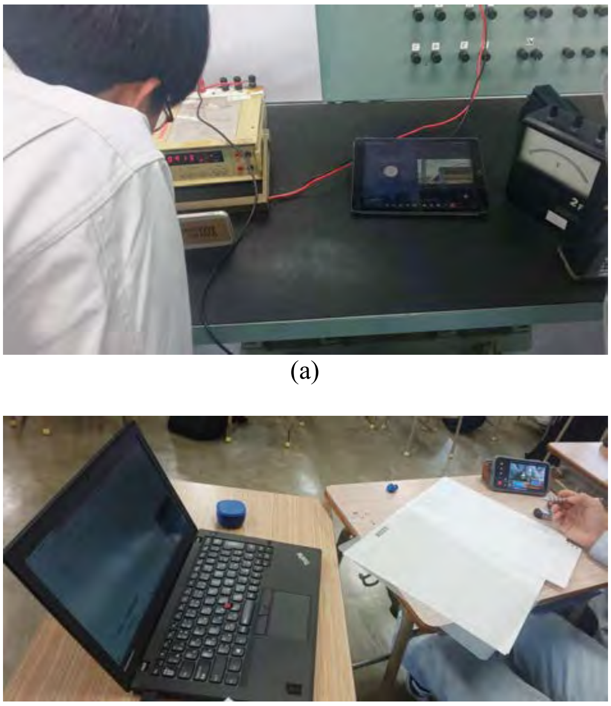


Figure 4 Conceptual diagram of remote experiment

Figure 5 shows the situation of each group. Each experimental group conducts experiments by communicating with each other while devising video chats, voice chats, sending images, etc.


(a)

(b)

Figure 5 (a)” experimental group”: Laboratory side in remote experiments (b) "instruction analysis group”: Home Room side in remote experiments

After the analysis team performs a simple analysis on the collected data, it is saved in Microsoft OneNote, shared with the team and with the instructor, and undergoes final checks. By using such a remote meeting tool, we were able to try remote experiments while maintaining social distance.

Grasping the time series of experiments and exchanging opinions using a web bulletin board

This time, Microsoft Teams was adopted for the student experiment in order to conduct the remote experiment as mentioned above. Using this communication tool, we conducted a trial of a web bulletin board for reporting/posting the progress of each experiment team's experiments, and for openly posting any troubles that occurred or problems that they had.

By the way, in this student experiment, multiple instructors are assigned to multiple laboratories and provide guidance. No TA was employed to advise individual experiments. Therefore, each faculty member cannot grasp the individual details of each experiment in real time. Now each experiment consists of a series of multiple mini-experiments. However, due to the placement of instructors as described above, the instructor can grasp the time series of the start and end of the entire experiment. On the other hand, it is impossible to grasp the timing of the start and end of small experiments (including the time required for preparation wiring). Therefore, we asked the student team leaders to post the start and end of each small experiment and the timing of preparations such as wiring changes on this WEB bulletin board as appropriate. Through this attempt, the instructor was able to grasp the detailed chronological order of each small experiment. Furthermore, by projecting the images of the web bulletin board on a large-scale display separately placed in each laboratory, each instructor and each student can easily check these at any time (Figure 6). As a result, information such as “Each small experiment or preparation took longer than expected by the instructor" or “The work was completed in an unexpectedly short amount of time" can be understood. This will provide basic data for future revisions or changes to the experiment. At the same time as reporting to the WEB bulletin board, we asked the students to write down their troubles and difficulties on this WEB bulletin board in real time. As a result, it has become possible to record the voices of students, who are difficult to record in lab notebooks and reports, and to use them to improve the contents of future experiments.

Figure 6 Web bulletin board projected on a large display in the laboratory

Results and Discussion

(1) This time, by using the KY sheet, we were able to turn the student experiment, which has a strong passive element, into a training ground for the student who is an engineer's egg who lives in an unpredictable age. In addition, we conduct a questionnaire for students asking what kind of items should be added to this KY sheet for better experiments. Based on the results, we will create better KY sheets and strive to foster awareness that students themselves are participating in the planning and management of student experiments.

(2) We tried a remote experiment as an emergency evacuation response to the corona disaster. In Japan, on May 8, 2023, COVID-19 will be treated as a normal infectious disease, and the COVID-19 disaster is converging on the surface. However, we still cannot afford to be complacent about the COVID-19 disaster. Also, even after the COVID-19 pandemic is over, the importance of remote work in the engineering field is expected to increase in the future due to reasons such as the shortage of skilled engineers, globalization, and the sophistication of technology. In that sense, the know-how obtained from this remote experiment is considered to be useful information. Also, this time it was a remote experiment on the premise that there was a working student in the laboratory. On the other hand, remote experiments in a completely remote environment are also envisioned. That is, the laboratory is unmanned, and the experiment operates the equipment from a completely remote situation. Of course, it will not be possible to realize remote experiments in all experiments. However, there is a possibility of realization in the electronic experiment dealing with electronic equipment. Currently, we are paying attention to the "Node-RED" system as a tool that may be able to realize remote electronic experiments. Learning this deeply, we would like to work on remote electronic experiments as student experiments.

(3) This time, we set up a virtual WEB bulletin board on Microsoft-Teams. By utilizing the immediacy of ICT and utilizing this WEB bulletin board, we were able to collect information on the progress of experiments, questions that arose, and problems that arose from students conducting experiments. Furthermore, I would like to explore the possibility of communication between instructors and students and between students in student experiments by using the reciprocity of ICT.

Conclusions

In this trial, by trying an active and interactive approach, we were able to stimulate the students' positive attitudes and awareness, and also enabled close information sharing between instructors and students. Through these attempts, we were able to foster scientific literacy. Through these attempts, I was able to transform from a "passive experiment" to an "active experiment." We hope that this attempt will help cultivate engineers who will open up the unpredictable after-covit19 era.

Acknowledgements

We are particularly grateful for the assistance given by the co guidance staff for this student experiment. This work was supported by JSPS KAKENHI Grant Numbers 23650521, 25560096, 15K12401 and 21K18545 (Grant-in-Aid for Challenging Exploratory Research).

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Research on multiplexing of remote experiments and training systems using container virtualization technology

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Abstract

While the number of online classes is increasing due to the spread of COVID-19 infection, it is difficult to implement practical classes using special equipment such as electrical circuit practice and experiment remotely. In a remote learning system using actual equipment, the number of students is large and the hardware scale of individual systems (servers) is large, which increases the time cost and hardware resources required to build and multiplex the experimental environment. This research aims to reduce both hardware and management costs by multiplexing experimental training systems on containers. Therefore, this research will minimize server hardware by using container virtualization technology for server construction. Container virtualization is a technology that creates an area called a container on the host OS and runs one container as one virtual machine, allowing the virtual machine to run with fewer resources than other virtualization techniques. In this research, a remote experiment system is constructed to learn digital circuit design with FPGA (Field Programmable Gate Array) board. Learners access the server container from a client PC via a browser to code, compile, and write a circuit configuration files to the practice board. The results of the experiment can be confirmed by immediately displaying the video captured by the FPGA board on the browser. The system is designed to enable this type of training. Build as many training containers as the number of training boards connected to the server using Raspberry Pi 3 to which the training boards and cameras are connected via USB. Docker will be used to build the training containers. It will implement and deploy a web server, web application, and FPGA development environment. After introducing the system, we will ask students to use this remote training system and evaluate usability and comprehension through questionnaires. In addition, the system will be compared with other virtualization methods and evaluated for resource reduction.

Keywords: *Containers, Virtualization, Remote Experiment, Multiplexing*

Introduction

Remote teaching has become possible through the development of video calls and web conferencing tools. With the spread of COVID-19 infection, educational institutions have developed remote teaching environments, which will continue to be used in the future. Jacko (2022) found it difficult to remotely conduct practical training using specialized equipment, such as circuit training and electrical laboratory exercises, and most training is conducted by simulation. However, a survey of students conducted at the Technical University of Košice shows that practical training using actual equipment is more desired than simulation. As a leading example of remote experimentation and practical training, Winzker (2020) offers remote classes on digital hardware image processing using FPGA boards at Bonn Rhein-Sieg University of Applied Sciences.

Figure 1 FPGA Remote Lab Overview

Nakata (2019) found that when a remote training system using experiment and practice boards is designed as a one-to-one user and server, the hardware scale becomes too large for a large number of learners to use, and the time cost and hardware resources increase for the development of the experiment environment and multiplexing of the system. In this study, container virtualization technology is utilized for server construction in order to minimize the hardware requirements of servers for remote practice environments. The objective is to multiplex experimental and practical training systems on containers to enable the reduction of both hardware and management costs.

This paper describes the configuration and implementation of a system that enables the remote operation of experiment and practice boards and real-time video confirmation of the operation results. This study proposes an online training system that utilizes containerized servers. We will implement the system, have users build the system, and collect questionnaires on the usability and multiplexing of the system. Then, we compare and evaluate the proposed system and the conventional system and show the superiority of the proposed system.

Virtualization of remote experimental systems using Docker

This study uses a container virtualization method as a virtualization method for individual experimental systems. Figure 2 shows the structure of the container-based virtualization method. Container virtualization creates an area called a container on the host OS and operates one container as one virtual machine. Table 1 shows a comparison with other virtualization methods. Figure 2 shows the configuration of container virtualization.

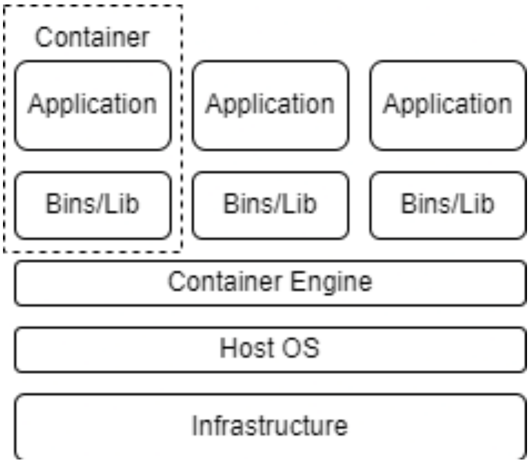


Figure 2 Container virtualization configuration

Table 1 Characteristics of each virtualization method

Virtualization method	Guest OS	Separation Level	Overhead	Augment ability
Hyper Visor	Required	High	Big	Low
Host OS	Not required	High	Big	Low
Containers	Not required	Low	Small	High

Host OS and hypervisor virtualization methods require a guest OS on the virtual machine when building a virtual machine on the host OS. This increases the independence of each virtual machine, but it tends to occupy a large amount of resources and increase the overhead. In addition, the scalability is low because a guest OS must be installed and initially configured each time a virtual machine is built. On the other hand, container-based virtualization does not require a guest OS, so virtual machines are less independent than host- and hypervisor-based virtualization but more scalable. In addition, virtual machines occupy fewer resources, allowing more efficient use of hardware resources such as CPU and memory, and have less overhead.

Docker is an open-source platform for creating, distributing, and running containers. Figure 3 shows an overview of Docker.

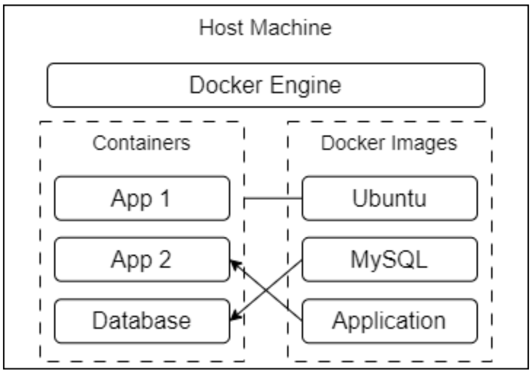
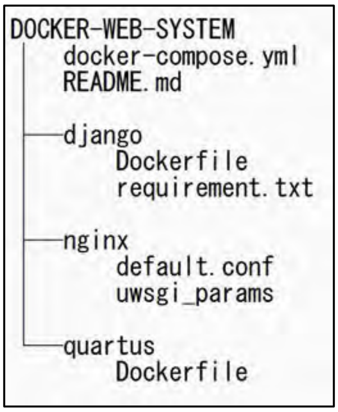


Figure 3 Overview of Docker

Docker builds a container by encapsulating an application and its execution environment using a static image on the file system called a Docker image. Users can use a Docker image creation function called Dockerfile to create a container image by themselves, which creates a file named Dockerfile and describes the base Docker image and commands to be executed in code-like format. Dockerfile is created by executing the build command from the Dockerfile in the Docker daemon.

Docker-Compose can be used to manage multiple containers by creating and configuring multiple container images at the same time. When building a container with Docker-Compose, users can create a directory structure as shown in Figure 4, and describe the basic information and configuration of the container to be created in docker-compose.yml. This allows for multiple containers to be multiplexed by specifying directories to be shared by multiple containers and by specifying container settings in a batch.



```
DOCKER-WEB-SYSTEM
│   docker-compose.yml
│   README.md
│
├─django
│       Dockerfile
│       requirement.txt
│
├─nginx
│       default.conf
│       uwsgi_params
│
└─quartus
        Dockerfile
```

Figure 4 Directory structure when building containers

Figure 5 shows the flow of the remote practice to be implemented in this study. An FPGA board is used as a practical example to implement a digital circuit operation experiment designed in Verilog HDL. The experimental procedure is as follows:

1. Students write a circuit in Verilog HDL.
2. The local circuit synthesis environment is used to generate circuit connection information for the FPGA.
3. Connect online to the training system server and upload the circuit connection information.
4. Confirm the operation of the FPGA board displayed on the screen in real time by operating switches from the screen on the practical training system.

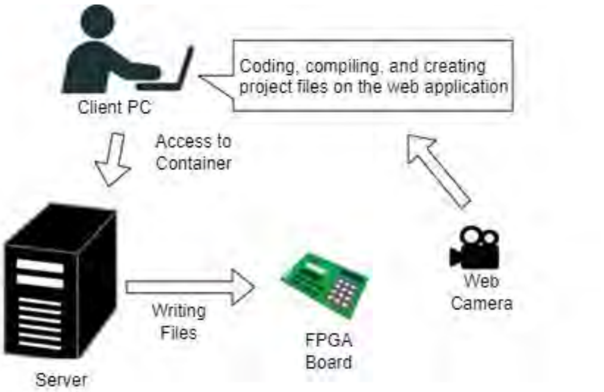


Figure 5 Assumed remote training flow

This digital circuit is implemented utilizing container virtualization. Figure 6 shows an overview of the training system.

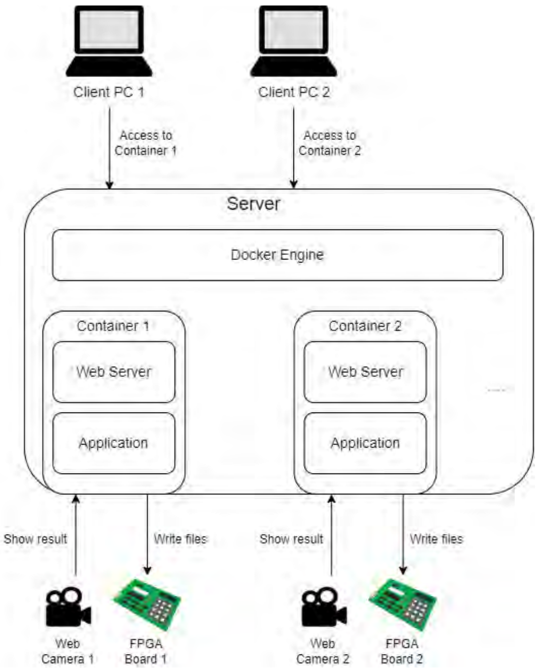


Figure 6 Overview of the training system

The host machine which serves as the server has multiple FPGA boards and cameras connected via USB. FPGA boards and cameras are the units of the training system and the server deploys the same number of containers as the number of training systems connected to the host machine.

When a student connects to the training system from a client, a screen that is a web application is displayed. This screen has the following functions:

- Upload Verilog HDL source code or circuit connection information
- Streaming display of the board
- Switch operation on the experimental board

The implementation of this system is described below.

Implementation of a digital circuit remote training system

The host machine is a Raspberry Pi3 Model B+ and the OS is Ubuntu Server 20.04. The development environment for the FPGA board is Altera's Quartus II Web Edition, which is an FPGA-integrated development environment by former Altera. We chose Raspberry Pi3 as the host machine because it is small and inexpensive, its low performance makes it easy to grasp the resource usage status when multiple students are connected to it, and it is easy to experiment with its operation response. The GPIO pins are used to simulate the operation of switches and buttons on the FPGA board.

Figure 7 DE2-70

Figure 9 shows the configuration of the containers. There is one training system for each FPGA board. The training system consists of a container that plays the role of a web server, a container that stores a web app implemented in Django ("Django container"), and a Quartus container that stores the functions of Quartus, an FPGA integrated development environment. We implemented the web server container, the Quartus container, and the web app container together using Docker-Compose, and built one web server per training board. In the initial configuration of this remote training system, we built one web server container and multiple Quartus containers for writing FPGAs on the host machine as shown in Figure 8, and the user selected the container to use after accessing the web server. However, in this method, the access to one Web server is concentrated and the independence of each experimental system is lost. Therefore, the simplicity of multiplexing, which is an advantage of container virtualization, cannot be satisfied.

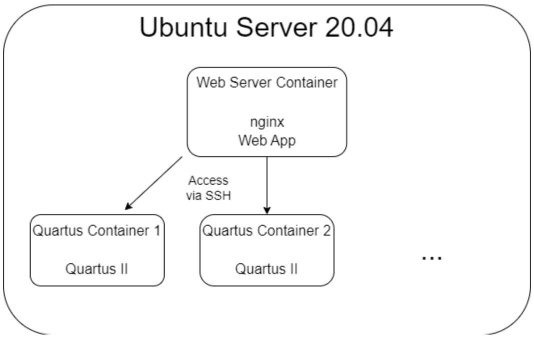


Figure 8 Initial container configuration

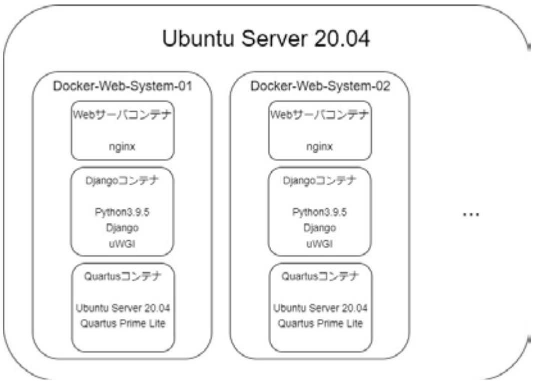


Figure 9 Container configuration after improvement

In the implementation phase, we implemented a web server container, a Django container, and a Quartus container. All of these containers were built together using Docker-Compose and Dockerfile.

The web server container is based on an Nginx container image, and port forwarding is configured in Docker-Compose. Figure 10 shows the port forwarding configuration.

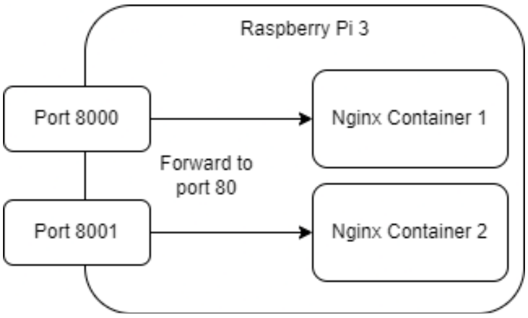


Figure 10 Port forwarding overview

When accessing the web server in the container from a client PC, we access the IP address of the host machine instead of the IP address of each Docker container. Therefore, when building multiple Nginx servers on a single host machine, we can configure port forwarding between the Nginx container and the host machine and build multiple web servers to be accessed by passing any port on the host machine to port 80 of the container.

The Quartus container was built based on Ubuntu in the Dockerfile, with Quartus II and the libraries necessary to run Quartus II installed. Quartus II executes coding, compilation, etc. on the GUI, and compiles and writes files on the command line, but it also provides an environment for executing these operations with console commands. This container contains the execution environment.

The Django container contains a web app implemented in Django, which is responsible for uploading files, creating project files, coding, writing files to the FPGA board, and other interface functions of the FPGA development environment. Figure 11 shows a mock-up of the Web app interface.

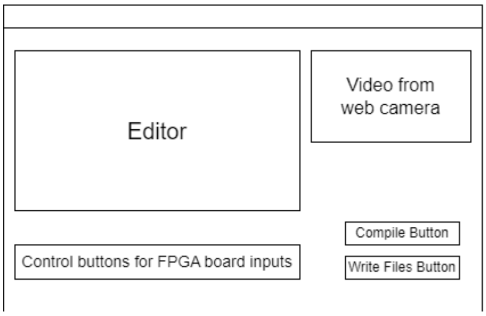


Figure 11 Mock-up of the Web app interface

We implemented a program in Python to write files uploaded from the web app to the FPGA board, and the Linux version of Quartus has a function to compile files by typing commands from the command line. We used Python's "subprocess" library to execute Linux commands from Django in a Quartus container based on Ubuntu Server 20.04. We need the USB port ID of the FPGA board when writing the file (project file) that contains the circuit connection information after compilation to the FPGA board by the Linux command. Therefore, the "lsusb" command includes a process to reference the USB port ID based on the device ID in advance.

We implemented these containers and confirmed that the project files were successfully written to the FPGA on the FPGA board. We built two containers and configured port forwarding between port 8000 and 8001 of the host machine and port 80 of the container, respectively, and connected two FPGA boards to Raspberry Pi and confirmed that writing was executed on each.

Conclusions

This study describes a method of implementing a remote practice system using container-based virtualization. a digital circuit design practice system using FPGA boards was constructed.

In the current container configuration, one FPGA board uses three containers internally. The system is built using Docker-Compose, which is easy to manage and maintain, but it has the disadvantage of creating three base Docker images, which has more overhead than if it were consolidated into a single image. In order to determine the optimal host server hardware and container implementation configuration, we would like to implement all functions in an Ubuntu Server-based container, compare the two in terms of processing speed, resource usage, and ease of maintenance, and determine appropriate specifications.

We will further implement the remote experiment system, increase the number of multiplexing units, have students use the system, and conduct a questionnaire on the ease of use and learning effectiveness of the remote experiment system to identify issues.

We plan to make improvements to both the hardware/web application to address the issues.

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Development and Implementation of Short-term Environmental Education Programs on $PM_{2.5}$ Using a Portable Sensor

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Abstract

In recent years, studies and analyses on fine particulate matter ($PM_{2.5}$) have been conducted, and environmental education on $PM_{2.5}$ has become increasingly important. However, there are few reports on environmental education materials on $PM_{2.5}$ that can be conducted in a short time. National Institute of Technology, Yuge College (NITYC) is located in Kamijima Town in the Seto Inland Sea, where high concentrations of $PM_{2.5}$ have been observed despite the island's remote location. Therefore, we proposed and implemented several environmental education programs using a portable sensor for $PM_{2.5}$ measurements developed at Nagoya University.

First, we observed the differences in $PM_{2.5}$ concentrations between different fuels when burning rocket stoves. It was confirmed that combining pine cones with firewood as fuel resulted in a decrease in $PM_{2.5}$ concentration and efficient combustion.

The cause of the high $PM_{2.5}$ concentration in Kamijima Town is not only long-range transboundary air pollution but also from local pollution such as field burning. Therefore, we used a portable sensor to measure the $PM_{2.5}$ concentration in Kamijima Town regularly by bicycle and created a $PM_{2.5}$ distribution map to analyze the air pollution in Kamijima Town. At the beginning of the measurements, stable readings were difficult to obtain due to vibrations from the road and sunlight. However, using a box to shield the light and cushioning material made it possible to obtain stable measurements. These experiments and measurements were carried out by NITYC students and allowed them to deepen their understanding of the atmospheric environment through discussion and analysis.

Finally, we conducted an outreach class at an elementary school by combining small $PM_{2.5}$ measurements with traditional gas detection tubes. NITYC students were the main teachers and gave lectures and explanations. The NITYC students and elementary school students who participated in these activities showed a great interest in the atmospheric environment, including $PM_{2.5}$.

Keywords: *Fine particulate matter （$PM_{2.5}$） , Environmental education, Portable sensor for $PM_{2.5}$ measurements,, Creation of $PM_{2.5}$ distribution maps, outreach class*

Introduction

In recent years, air pollution such as fine particulate matter ($PM_{2.5}$) from China has been attracting attention, and analysis and research on this issue are being conducted in many fields. In this context, environmental education on $PM_{2.5}$ is becoming increasingly important, but there are still few reports on environmental education materials on $PM_{2.5}$ that can be implemented in a short-term. National Institute of Technology, Yuge College (NITYC) is located in Kamijima Town in the Seto Inland Sea, has been conducting research since 2012 on $PM_{2.5}$ measurements and its impact on students' health. As a result, high concentrations of $PM_{2.5}$ have been observed. These results have been reported not only in Kamijima Town but also in most around of the Seto Inland Sea, and research is currently underway to determine the cause.

Under these circumstances, Nagoya University has provided us with a portable sensor for $PM_{2.5}$ measurements developed jointly by the university and Panasonic. This portable sensor uses the light scattering method, and because of its high performance and palm-size, it can be used for simple measurements anywhere . We propose an educational program using this portable sensor and report on the results of its implementation.

Measurement of $PM_{2.5}$ Concentration Using a Rocket Stove

A rocket stove is a device that incorporates a chimney, such as an L-shaped pipe into 18-liter square can or pail and uses the natural heat rise to achieve efficient combustion with less fuel and smoke. As such, they are environmentally friendly and have attracted much attention since they were used in the Great East

Japan Earthquake. We have studied the development of small rocket stove education materials that can be used in the classroom, as well as their use in times of disaster, such as shower and power generation . While rocket stoves are known for their ability to burn various types of fuel, the combustion process differs depending on the fuel used. When rocket stoves are used in evacuation centers during a disaster, there is concern about $PM_{2.5}$ pollution from the smoke. Changes in atmospheric $PM_{2.5}$ are long-term, and there are few examples of short-term $PM_{2.5}$ concentration measurements for environmental education. Therefore, for the education and fuel selection during disasters, we investigated the measurement of $PM_{2.5}$ concentration changes due to differences in fuels using a portable sensor.

We used a typical rocket stove using a pail and different fuels, including firewood, chopsticks, driftwood, pine cones, and bamboo (Figure 1).

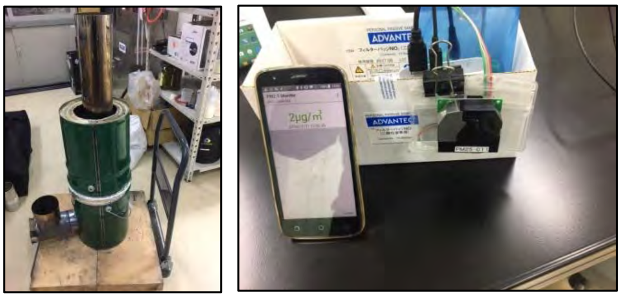

Figure 1. Rocket stove and portable sensor for measurement of $PM_{2.5}$ concentration

The results are shown in Table 1. A significant change in $PM_{2.5}$ values was observed when the fuel was changed. It was confirmed that the system can be used in the class for a measurement of $PM_{2.5}$ concentration in a short period of time. While bonfires emit more than 30 $\mu g/m^3$ of $PM_{2.5}$, when disposable chopsticks and firewood were used, $PM_{2.5}$ concentrations were low, around 10 $\mu g/m^3$, a range suitable for use in evacuation centers. When bamboo was used, combustion was stronger, but $PM_{2.5}$ concentrations were higher, ranging from 8 to 20 $\mu g/m^3$. When driftwood was used, $PM_{2.5}$ concentrations ranged from 20 to 60 $\mu g/m^3$, which is not suitable for use in evacuation centers. When pine cones were used as fuel, the fire power was stronger and there was almost no $PM_{2.5}$ emission. Combined with pine cones, the concentration of $PM_{2.5}$ was less than 30 $\mu g/m^3$ even in driftwood. Additionally, when the length of the chimney was doubled, $PM_{2.5}$ concentrations were even lower (Data not shown). By changing the combination of fuels and the length of the chimney, stable combustion with relatively low $PM_{2.5}$ values was possible, and it was confirmed that the fuels can be used sufficiently in evacuation areas.

Table 1. $PM_{2.5}$ concentration changes due to differences in fuels

Fuels	$PM_{2.5}$ concentration (μg/m$^{3)}$
Pine cones	~ 5
Chopsticks / Firewood	~ 10
Bamboo	8 ~ 20
Driftwood	20 ~ 60
Pine cones + Driftwood	~ 30

Creation of $PM_{2.5}$ distribution map of Kamijima Town

Various causes of the high $PM_{2.5}$ observed in the Seto Inland Sea have been considered, including the influence of the region's geography, pollution from nearby factories and ships, and transboundary pollution from the continent. In addition, open burnings are still being conducted in Kamijima Town, which is considered a local source of high $PM_{2.5}$ concentration. Therefore, to analyze the causes and construct a more experiential environmental education, we measured $PM_{2.5}$ in Kamijima Town using a portable sensor and create a distribution map of $PM_{2.5}$ concentration. Conventionally, the creation of a distribution map using the portable sensor is done by walking, which requires time to measure a long distance. In addition, cycling is popular in Kamijima Town. Therefore, in this study, we measured once a week at a rate of 6 to 7 minutes per kilometer by bicycle around a cycling course. Initially, there were many cases of sudden increases in the measurements. we considered to be caused by the sunlight and the slight vibration of the bicycle due to the road. To resolve this issue, we created shade by placing the device in a box and used a mat made of glass wool to reduce vibrations, enabling more stable measurements (Figure 2). The $PM_{2.5}$ concentration and GPS date stored on a tablet device were processed in Excel, and a distribution map was created using the web service GPS Visualizer (Figure 3).

Figure 2. The $PM_{2.5}$ measurement by bycicle

Based on the distribution maps, we discussed with the students to deepen their knowledge of the atmospheric environment. The following is a brief summary of the results.

- Higher $PM_{2.5}$ concentrations were observed in areas near the port, as well as in secluded areas and uphill locations.
- High $PM_{2.5}$ concentrations were observed at the waste treatment center and the sewage treatment center.
- The difference in $PM_{2.5}$ concentrations between high and low was more clearly observed in winter than summer.
- Locations suspected of open burning showed higher $PM_{2.5}$ concentrations.
- In higher altitude areas, higher $PM_{2.5}$ concentrations were observed.

These results were reported to the elementary school students as described in the next chapter, and not only the NITYC students, but also the elementary school students deepened their knowledge of air pollution in Kamijima Town.

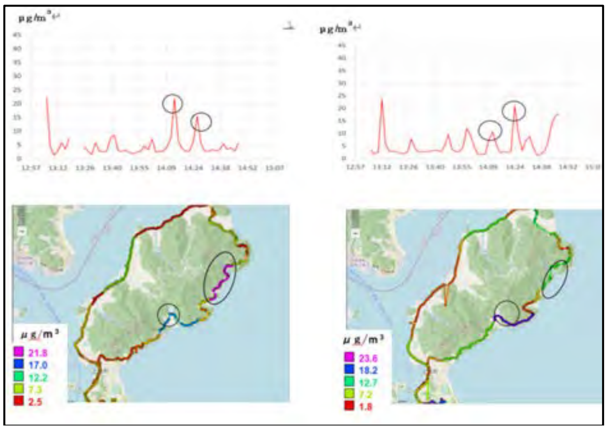

Figure 3. A example of the distribution maps created

Outreach class by NITYC students at elementary school

There is only one elementary school on Yuge Island, where NITYC is located, and environmental education in remote areas is limited. In addition, there are few reports on hands-on atmospheric education for elementary school students on $PM_{2.5}$. Therefore, NITYC students conducted preliminary learning on $PM_{2.5}$ and delivered outreach class using portable sensor. The lessons were held for fifth-graders in 2021 and 2021. The lesson content was proposed by the students. The participating students were first- to third-year students of the science club and students involved in the experiments in the previous chapter, in addition graduates of the elementary school. It was a refreshing activity for the students who taught.

The class was conducted in a lecture format, combining an introduction to the atmospheric environment of Kamijima Town with experiments. Gas measurements included measuring $PM_{2.5}$ concentration using portable sensors and measuring the concentrations of carbon dioxide, oxygen, and carbon monoxide using gas detection tube devices (GasTech). Atmospheric measurements were conducted not only in the classroom and schoolyard but also measuring car exhaust and incense smoke (Figure 4,5,6).

Figure 4. Lecture by NITYC students

Figure 5. Gas measurements using gas detection tube devices

Figure 6. Atmospheric measurements in schoolyard and car exhaust

The results of the questionnaire from outreach class is shown in Table.7. As a result, a large number of students indicated that their interest in the environment and science was promoted, and none were not. Because the elementary students had not learnt about the composition of air and how to measure gases , so it can be seen that the majority understood the lecture, although some students stated that it was a little difficult for them to understand. Some of the free-response statements from the questionnaire are shown below. It is clear that the students took the lecture seriously.

- I was surprised that the concentration of $PM_{2.5}$ was high even in Kamijima Town, which I thought was clean.
- I enjoyed using the gas detector tubes and portable sensor.
- the PM2.5 concentration increased due to car exhaust gas. It made me think more about environmental issues.

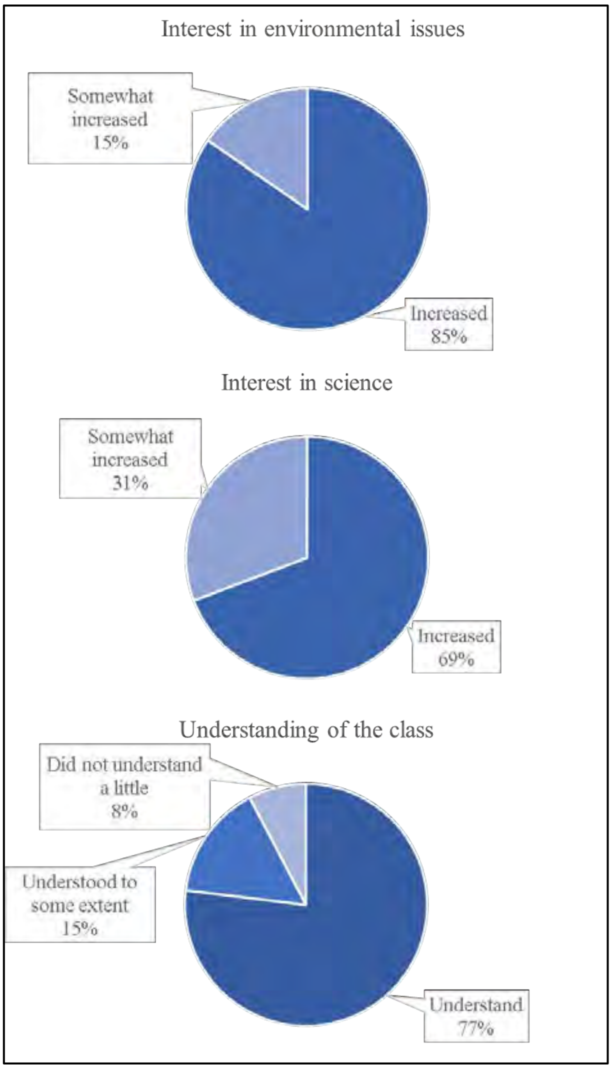

Figure 7. Results of the questionnaire from outreach class

Conclusions

NITYC defines "remote island engineering" as activities to solve problems faced by remote islands from an engineering perspective in cooperation with local communities. These activities aim to develop human resources who can contribute to the "safety and security" of the local community through research and education in a wide range of fields, including disaster prevention, IoT, robotics, energy, logistics, environment, and welfare, as well as volunteer work for the community. This activity is also an activity to learn about the atmospheric environment of Kamijima Town, to share information with community and to find solutions to the problem. Based on the distribution map, it is possible to use it for controlling sources of $PM_{2.5}$, such as field burning. In the future, there is an expectation to develop an application that can inform users about locations where high concentrations of $PM_{2.5}$ are predicted by integrating it with real-time atmospheric conditions. This application can be utilized in activities such as cycling and jogging. In addition, disaster prevention and the environment are very closely linked. In a disaster, water availability is important, and at the same time it is necessary to know the water environment. Air pollution is also a concern in disasters, and this activity also involved measuring $PM_{2.5}$ in combination with rocket stoves. This activity is part of a series of activities that also take water environment and other disaster prevention into consideration, and will be continued in the future.

Acknowledgements

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THE EFFICACY OF 3D-PRINTED MODELS IN THE LEARNING OF SPATIAL CONCEPTS IN CHEMISTRY

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Abstract

Spatial concepts and intermolecular interactions play a pivotal role in chemistry. There is a dire need for supplementary approaches to support meaningful learning in chemistry. In this study, the employment of ball-and-spoke and space-filled type coloured 3D-printed models in explaining spatial concepts such as aromaticity, stereochemistry and substitution reaction were explored. Specifically, the study examines the learners' motivation and perceived learning through mixed methods of quantitative survey and qualitative focus group discussion (FGD).

After a three-week exposure to three sets of 11 models, there is a statistically significant ($p<0.05$) increase in learners' overall motivation. Data from the perceived learning survey confirmed: a) 3D-printed models help the learners in visualization of sub-microscopic spatial concepts; b) models were perceived to be useful for learning and c) dual usage of both ball-and-spoke and space-filled type models simultaneously helped them to remember substitution (SN) reaction. These results were triangulated by focus group discussion (FGD) which indicated that the learners find 3D-models aid clarity through 3D visualization; assist recollection of concepts through colour coding and add fun through interactions. The authors recommend the continued use of the 3D-printed models and the expansion to other lessons of the chemistry module.

Keywords: *Interactive Seminar, 3D-printed models, motivation, Self-Efficacy, Perceived Learning*

Introduction

According to Johnstone's triangle model (Johnstone, 1991; Johnstone, 1993), chemical information can be represented simultaneously at multiple levels, such as the visible macro level or description, the unseen sub-micro level or explanation, and the abstract symbolic level or representation. An expert instructor may find it easy to work with this perceptual triangle and change between levels, however, this may not be the same for a novice or learner (Johnstone, 1991; Johnstone, 1993). Some reasons could be attributed to the novice's prior knowledge required in progressive learning (Lowe, 1999), attitudes to study including level of engagement and perception of relevance (Minasian, Lingard, & Prosser, 2005), as well as capacity to grasp abstract concepts (Dori & Barak, 2001). Moreover, introductory-level instructors find it difficult to teach the realm of macrocycles, chirality and molecular interactions beyond simple molecules (Mohamed-Salah, & Alain, 2016; Stull, Gainer, Padalkar & Hegarty, 2016). Hence, challenges for chemistry instructor include finding novel ways to simplify complex concepts, assist learners in overcoming 3D visualisation challenges, enhance learners' motivation, and improve learners' engagement in the learning process.

There appears to be a paradigm shift in chemistry education, over the last 15 years involving the use of supplements in instruction, such as 3D-printed models, educational games and laboratory simulations which have been trialled to engage learners in interactive and enjoyable learning (Samide & Wilson, 2014; Kaliakin et al., 2015; Castro-Godoy et al., 2018; Blackburn et al., 2019; Richards, 2019; Cevallos, 2020; Diaz-Allen & Sibbald, 2016). The need for supplemental approaches to support meaningful learning in science is pressing as the traditional methods of instruction and learning promote rote memorization which may lead to superficial understanding (Bhattacharyya, & Bodner, 2005; Grove & Lowery Bretz, 2012; Griffith et al., 2016; Carroll, 2010). The use of customized 3D-printed models allows educators to design rich learning experiences, impart skill development, boost interest and increase learner-teacher engagement (Berry et al., 2010). Moreover, 3D-printed models can provide unique insights to illustrate molecular structure enabling physical hands-on experience in rotating and translating the structures (Cooper & Oliver-Hoyo, 2017; Penny et al., 2017; Jones & Spencer, 2018; Van Wieren et al., 2017; Meyer, 2015). Though ball-and-spoke models have been used in teaching metal complexes and structures in excess of 15 carbon atoms become cumbersome, too large in size, expensive, and subject to mistakes and breaking (Van Wieren et al., 2017). To bridge this gap 3D-printed tactile models consisting of both ball-and-spoke as well as space-filled types were developed and deployed as cognitive tools in learning activities. Consequently, this study addresses the following research questions:

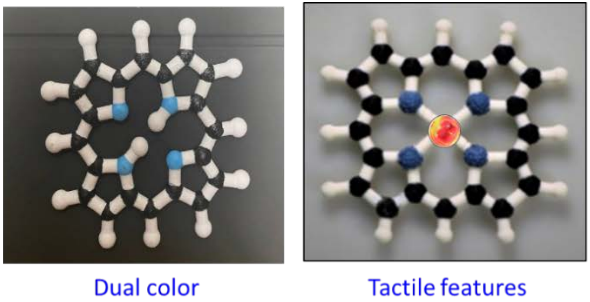
RQ1: What effects do 3D-printed models have on learners' motivation with respect to task value (TV) and self-efficacy (SE)?

RQ 2: How do learners perceive their learning of chemistry concepts when 3D-printed models are used in learning activities?

Development of physical molecular visualization models

The 3D models were printed using the institution's makerspace facility which is an open collaborative workspace with tools and technology. The models were designed according to Corey−Pauling−Koltun (CPK) color coding (white for hydrogen; black for carbon; blue for nitrogen; red for oxygen etc.). These 3D-printed models were aligned to facilitate learning of spatial concepts, namely, macrocycles, stereochemistry and stereospecific ligand-receptor binding, as well as reaction mechanisms. The composition of the models were ball-and-spoke type porphyrin and metal porphyrinate complexes (Figure 1) with light balls representing various metal ions like Mg^{2+}, Fe^{2+}; stereoisomers of cetirizine and tubocurarine contributing to the ball-and-spoke type (Figure 2); set of space-filled and commercially available ball-and-spoke models of primary, secondary, tertiary alkyl halides and a nucleophile (Figure 3).

Figure 1: *Ball-and-spoke models i) dual-color printed porphyrin; ii) textured metal porphyrinate model.*



Dual color

Tactile features

Figure 2: *Textured models of cetirizine and tubocurarine stereoisomers*

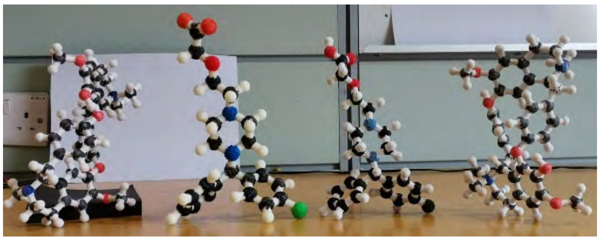
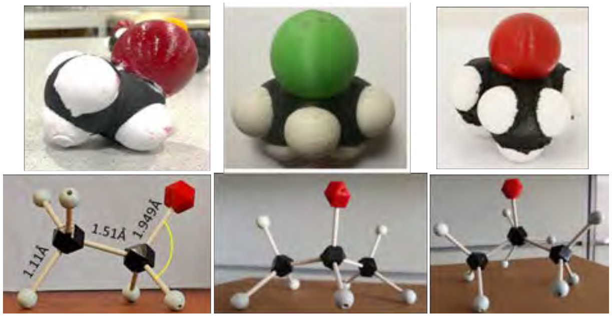


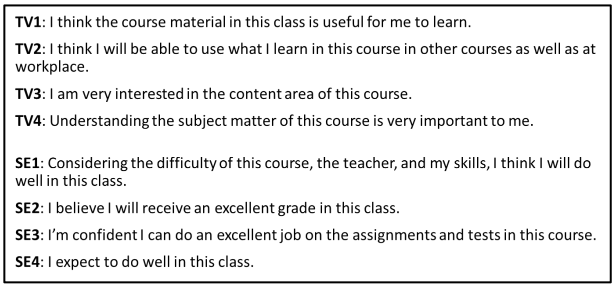
Figure 3: *Both space-filled models and ball-and-spoke models of a 1° / 2° / 3° alkyl halide*



Methodology

Learning activities were designed with these 3D models embedded in a second year Chemistry module. In week 2, learners discussed aromaticity, metal binding and color. In week 3, chirality in cetirizine and tubocurarine models and their stereospecific binding with receptor was incorporated in students' case studies whereas learners were asked to explain the ease of S_N2/ S_N1 reaction for each of the substrate models in week 4. A survey measuring TV and SE were adopted from the Motivated strategies for Learning Questionnaire (MSLQ) (Duncan & McKeachie, 2005), on a 5-point Likert scale, was randomly administered to 87 second year Chemistry learners in week 1 (i.e., pre-intervention survey) and at the end of week 4 (i.e., post-intervention survey). Self-efficacy (SE), as proposed by Bandura (1986), is a person's judgment about his or her ability to organize and execute courses of action to produce the desired outcome. Task value (TA) is defined as the incentive for engagement in academic activities (Wigfield & Eccles, 1992). Figure 4 lists the eight identical items that were used in the pre and post-interventional motivation survey. The paired t-tests were applied to analyse the change in learners' motivation in TV and SE.

Figure 4: *Eight Likert statements in motivation survey*



TV1: I think the course material in this class is useful for me to learn.

TV2: I think I will be able to use what I learn in this course in other courses as well as at workplace.

TV3: I am very interested in the content area of this course.

TV4: Understanding the subject matter of this course is very important to me.

SE1: Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

SE2: I believe I will receive an excellent grade in this class.

SE3: I'm confident I can do an excellent job on the assignments and tests in this course.

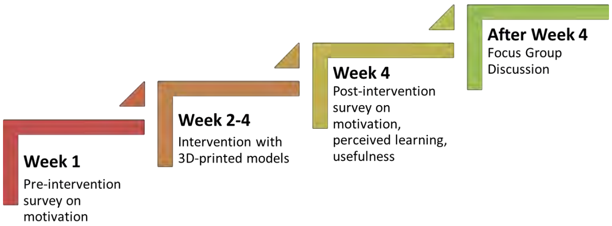
SE4: I expect to do well in this class.

To measure perceived learning, a survey consisting of sixteen items, with 5-point Likert scale, adapted from Gogal et al. (2017), Barzilai & Blau (2014), Davis (1989), and Sousa Lima et al. (2019) were administered randomly as a post-survey to the second year Chemistry learners (N=87). This survey gleaned information related to learners' perceptions of visualisation of spatial concepts, recollection of information, and usefulness of the 3D models in their learning.

FGD was used to garner learners' feedback on the effects of the 3D models on perceived learning, motivation and usefulness of the models in learning spatial concepts during activities. A purposively chosen sample of learners (N=10) across four classes, chosen according to their continuous assessment grades from A to C grade in week 3, were invited to participate in the FGD.

The research process is succinctly encapsulated in Figure 5.

Figure 5: *Design of data collection*



Results and Discussion

Motivation

Paired t-tests were applied to measure the change in learners' motivation using the pre- and post- intervention survey of overall motivation, TV and SE. There was a significant increase in learners' overall motivation scores between pre-survey (M = 3.71, SD = [0.39]) and post-survey motivation scores (M = 3.81, SD = [0.46]); t(88) = [-1.84], p = [0.034]). Furthermore, there was also a significant difference between pre SE scores (M = 3.39, SD = [0.74]) and post SE scores (M = 3.61, SD = [0.76]); t(88) = [-2.79], p = [0.003]. However, there was no significant difference in pre TV scores (M = 4.04, SD = [0.36]) and post- TV scores (M = 4.02, SD = [0.44]); t(88) = [0.33], p = [0.372]. These results suggest that 3D-printed models significantly increase the SE aspect of motivation. It may be due to actuation of thinking process by model's haptic perception when learners are immersed in kinaesthetic learning activities. Furthermore, the availability of the model throughout multiple learning phases enables them to visit and re-visit the spatial concept at any time throughout the day may lead to the engagement at the higher level of Bloom's taxonomy (Michael & Coffman, 1956).

Perceived learning

Data shows more than 75% of the learners responded favourably (i.e., either agree or strongly agree) to the items that corresponded to perceptions of visualization of spatial concepts, recollection of information, and usefulness of the 3D models in their learning. Additionally, 78% of the learners reported that they would want to engage in this mode of learning where content is infused with 3D models and approximately 72% would recommend their peers to use 3D models in learning Chemistry. Since the means of all items were greater than the mid-point of their scale, there is positive response to the use of these 3D models in learning the Chemistry concepts as seen in Table 1.

Table 1: *Perceived learning and usefulness of the models*

Statement	Mean (N=87)
I think 3D-printed models allowed me to visualize spatial concepts in organic chemistry more effectively	4.11
Use of 3D models will help me remember the concepts I learned about SN reaction mechanisms	3.77
Using 3D models added to my knowledge about substitution reactions	3.90
3D models were useful for my learning of spatial concepts	3.95
I would recommend this tool (3D-printed models) to my peers and juniors	4.00
I want to engage in this mode of learning more often	3.92

Focus group discussion

Thematic analysis was used to analyse how leaners view their experience with 3D models and three themes emerged- Interactive, Innovative and Interesting. FGD with learners further affirmed favorable responses towards the use of 3D models in the learning of Chemistry. Main benefits associated with the use of 3D-printed models include: 1) aid clarity through 3D visualization and hands-on experience; 2) assist recall concepts through colour coding; 3) fun through interactions which keeps learners awake. These are examples of students' feedback acknowledging the benefits. "*ability to physically hold and move helps visualize stereochemistry of molecules better*" *(Student, Year 3); "hidden part of the molecule becomes apparent in 3D with visualization of hybridization at each atom" (Student, Year 3).*

However, top two challenges include fragile nature of the models and inability to see the spokes /bonds through the space-filled models unlike ball and spoke models. While comparing ball and spoke models, a student mentioned *"bond was not visible easily in space filled models" (Student, Year 3).* Hence, top suggestions included enhancing bond strengths and filament material properties.

3D-printed models were observed to establish an engaging teaching environment by facilitating meaningful communication in learner-centric classroom setting. A similar finding was reported by an earlier work of Tversky (2002).

Conclusions

The 3D-printed models could explain multiple concepts simultaneously like valency of carbon and nitrogen, planarity in aromatic heterocycles/ macrocycles, difference between covalent vs co-ordinate covalent bonds, different metal ions impart different color to the metal porphyrinate complex. Keeping uniform CPK color codes for all the subsequently exposed models enables learners' understanding of the atomic connections. Similarly, these reusable CPK color coded 3D models help the learners to appreciate and visualize the 3D structure and shape of a drug/biomolecule as opposed to its 2D structure drawn on a white board. The concept of stereospecific binding of the drug (*l*-Cetirizine/*d*-tubocurarine) to its receptor site can be observed easily (Figure 2). By experiencing both the ball-and-spoke as well as space-filled models, the learners in organic chemistry students are able to visualize role of steric hindrance in reaction mechanisms.

From the data analysis, it can be concluded that the inclusion of 3D-printed models in kinaesthetic learning activities has the potential to increase learners' motivation with respect to SE. Furthermore, learners perceived these 3D printed models to be useful for learning spatial concepts as well as aid in easy recollection of information. Learners reported favourably to be engaged in such learning infused with 3D models. These models provide better visualization of chemical properties like aromaticity, color, chirality, stereospecific binding of ligands with receptors as well as the relative ease of S_N2 Vs S_N1 reaction mechanism. For an instructor, these 3D-printed models promote faster achievement of learning outcomes with reduced time required in explanations. This study has the potential to moot for continued use of the 3D models in curriculum delivery of Chemistry concepts.

It is envisaged that the simultaneous employment of 3D models together with a visualisation software may further enhance the effectiveness of teaching spatial concepts. With the 3D printing of models, instructors can easily prepare larger customizable, CPK color-coded models using readily available and economical filaments for classroom demonstrations without compromising the features on the surface.

Additionally, such 3D models can be used in the teaching of Chemistry concepts at secondary school level too. Consequently, these models may be used for science communication, public outreach, science centre and even decoration purposes of educational classrooms, museums and any other such facility.

The authors believe the textured 3D-printed models prepared in this study may provide concrete representations of computer generated images for learners who are blind or visually impaired. It is thus envisaged that this study has the potential to influence curriculum developers teaching spatial concepts to include customized 3D models in pursuit of achieving higher learner SE. Future work will also include testing the impact of the models on a larger number of students to increase the sample size.

Implications for Teaching

When teaching these concepts, faculty is encouraged to use activities incorporating the models to aid explanation. Moreover, as part of assessment students should be invited to propose explanations using these models to support their claims.

Acknowledgements

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DEVELOPMENT OF CYBER RANGE FOR OPERATIONAL TECHNOLOGY USING OPEN SOURCE SOFTWARE

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Industrial control systems such as factories, power plants, and transportation systems are used in various social infrastructures. Networked control systems offer benefits such as remote monitoring and operation of control systems and intelligent systemization. However, most communication protocols for ICS were designed without cybersecurity in mind. A cyber attack on an ICS, instead of an attack on an information system alone, can directly affect the physical object. Incidents can shut down processes controlled by the ICS and services provided by the ICS or deliver products that do not meet product requirements. Incidents can also result in lost opportunities by disrupting the production or shipment of products containing hazardous materials. Therefore, operational technology (OT) cybersecurity is critical in protecting the industrial environment and infrastructure.

OT cybersecurity training requires the creation of a test environment that closely resembles a real-world environment, including PLCs and control devices. However, vendor-supplied PLCs are subject to restrictions such as disclosure and confidentiality.

In this study, we developed cybersecurity training materials using OpenPLC, an open source system without such restrictions. The human-machine interface (HMI) was developed using the open source software Node-RED.

The developed system allows students to learn about cyber-attacks and dangers on ICSs, such as information theft through man-in-the-middle attacks and malfunctions caused by cyber-attacks on vulnerable protocols.

Keywords: *cyber range, OpenPLC, cyber security education, operational technology, open source software, Node-Red*

Introduction

Until now, cyber-attacks have mainly targeted information systems such as web services, e-mail systems, and corporate business systems. Cyber-attacks were mainly aimed at stealing companies' corporate intellectual property and personal information, as well as system downtime and tampering. Recently, however, social infrastructures such as factories, power plants, and transportation systems have begun to be targeted, and there is a concern that systems that provide social services and maintain safety may be attacked. Industrial control systems have been considered relatively safe from network attacks, but in recent years, the number of cyber-attacks has increased.

In 2010, malware called Stuxnet infected the industrial control system of a nuclear facility in Iran, causing it to malfunction. In 2015, a cyber attack caused a massive power outage in Ukraine, profoundly impacting people's lives. Cyber attacks on industrial control systems have continued to increase since then, and there is a shortage of security personnel in industrial control systems, making training such personnel an urgent task. However, security education for industrial control systems has been conducted infrequently, and there needs to be teaching materials for security education, in contrast to security personnel training for information systems.

As part of efforts to develop human security resources, some higher education institutions are conducting training in the form of practical exercises. Exercises are conducted using specialized experiential learning tools, and exercises are conducted using a cyber range that enables training based on actual security incidents. Exercises using the Cyber Range can be conducted in a virtual environment that simulates an existing system, and assuming actual incidents, it is possible to conduct highly realistic and practical exercises. , While recognizing the necessity of a training system, the introduction of Cyber Range has not progressed due to the high introduction cost. There are confidentiality obligations regarding high cost and vulnerability. Therefore, there is almost no cyber range for industrial control.

In this research, We created exercise materials using OpenPLC, open software not subject to such restrictions. In this teaching material, you can learn about network attacks related to PLC. In this paper, we report the outline of this teaching material and the result of education.

System Overview

(a) Software system

Figure 1 shows the architecture of a typical industrial control system. The system consists of field devices, PLCs that control them, and a Human Machine Interface(HMI), Supervisory Control, and Data Acquisition (SCADA).

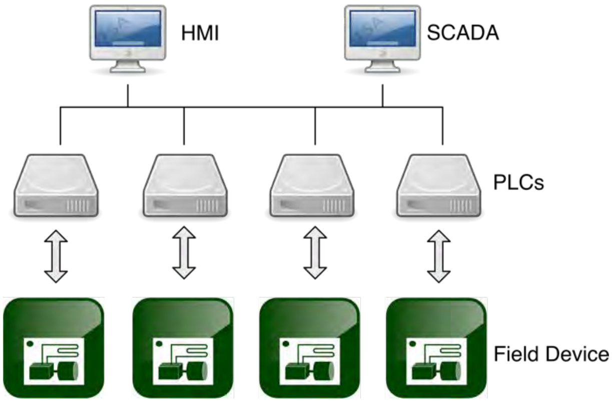


Figure 1 Typical Industrial Control System

The developed system consists of OpenPLC runtime, field devices, signal input interface, and SCADA. Node-RED can be used as SCADA to link with external databases and control network devices flexibly.

OpenPLC, an open source project, was used for the PLC part. The OpenPLC consists of the OpenPLC Editor for PLC program development, the runtime for executing the program, and the HMI Builder for providing SCADA and HMI environments.

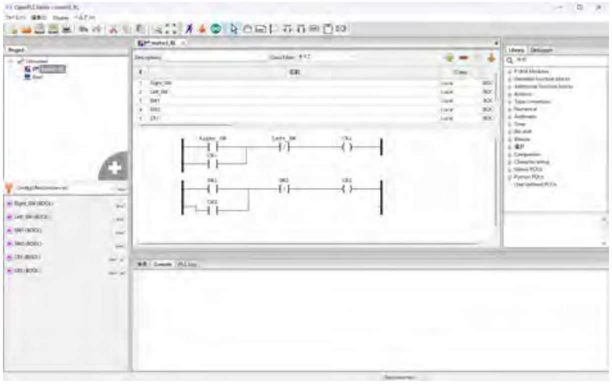


Figure 2 OpenPLC Editor

The software architecture of the OpenPLC Editor was developed by IEC 61131-3, the international standard for PLC programming languages, and includes the following development languages: Ladder Diagram (LD language), Function Block Diagram (FBD language), Structured Text (ST language), and Function Block Diagram (ST language). Structured Text (ST language), Instruction List (IL language), and Sequential Function Chart (SFC language) are available as development languages, providing a global standard development environment.

Figure 3 Human Machine Interface

The OpenPLC runtime supports the Raspberry Pi and FreeWave ZumLink 900 series embedded system platforms and software runtimes running on Windows and Linux. Furthermore, by connecting an Arduino as a slave device, it can function as I/O for the software PLC, and I/O points of the embedded system platform can be extended.

HMI and SCADA were built using Node-RED. Figure 3 shows the operation screen of the developed HMI system, which consists of a display of digital signals input to the PLC runtime, control status of external devices, analog signals from sensor devices, and operation/stop buttons for control devices. Figure 4 shows an overview of the cyber range developed.

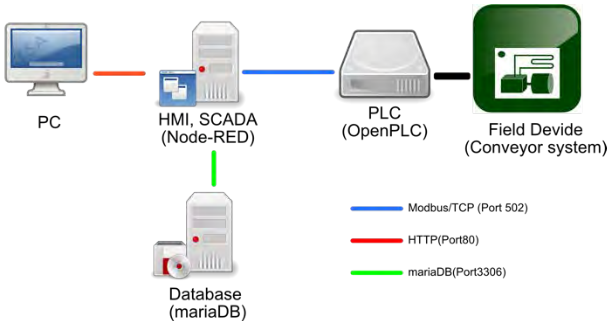


Figure 4 Cyber Range Overview

The communication between OpenPLC Runtime and SCADA uses Modbus/TCP. This open protocol uses the TCP/IP application layer to communicate, so there are no restrictions on the physical layer, allowing the system to operate in remote locations far from the experiment.

The system uses a polling cycle of 100 ms, and the SCADA system display is updated every 100 ms.

(b) Hardware System

Figure 5 shows the overall configuration of the developed PLC experiment device. The control program developed by Open PLC is sent to the Raspberry Pi and executed. Using Arduino Uno as a remote I/O device provides the following advantages.

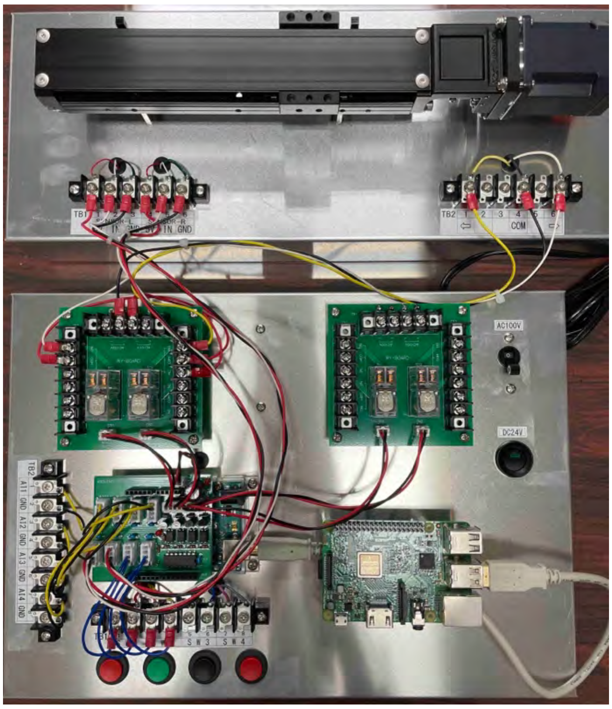


Figure 5 Overview of Hardware System using OpenPLC

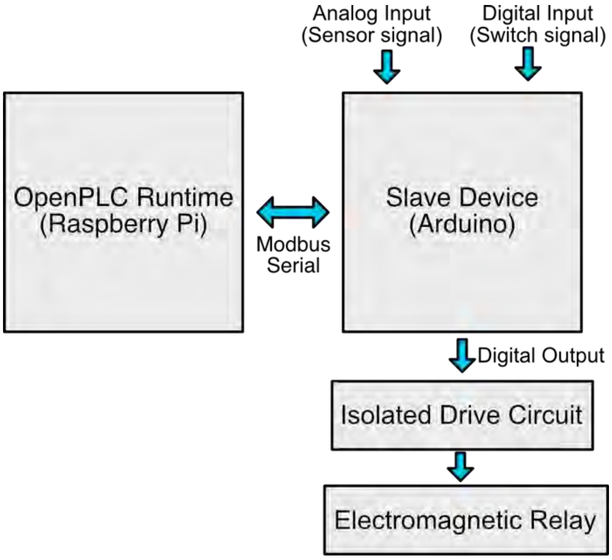


Figure 6 Overall Structure of the Control Circuit

The Arduino Uno's analog input terminal can handle analog signals, such as signals from sensors.

The digital input terminal can be used to input 5V signals, commonly used in education. The number of analog output terminals can be increased. The electromagnetic relay used for control is a 24 V drive relay commonly used in control panels. Figure 6 shows the overall structure of the control circuit.

An isolated drive circuit was fabricated to drive the electromagnetic relay. Figure 7 shows the configuration of the drive circuit. A photocoupler is used to convert the Arduino Uno's output voltage to the electromagnetic relay's voltage.

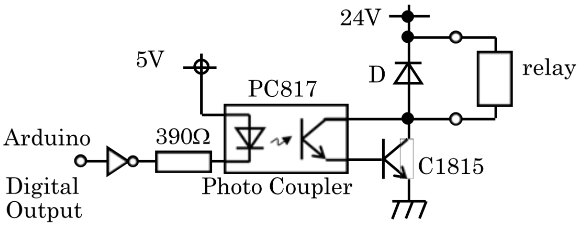


Figure 7 Drive Circuit

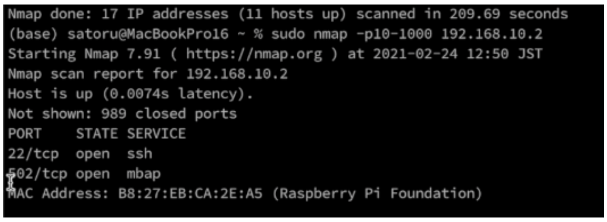
The interface circuit consists of an analog signal input section, a digital signal input section, and an isolated relay drive circuit. Elements necessary for control, such as sensors and switches, can be easily connected via connectors. Pull-up resistors required when using switches are mounted on the board, and a footed pin socket is used for connection to the Arduino Uno, which can be easily connected by inserting pins into the Arduino Uno's pin socket.

Training Scenarios

(a) Reconnaissance

Network reconnaissance is an essential part of the early stages of a cyberattack. Detailed information about a target's network can provide insight into the target's infrastructure and potential attack vectors and exploits that lead to vulnerabilities. Attackers can use passive and active reconnaissance tools and techniques to retain large amounts of information while reducing the likelihood of detection.

In this scenario, the network analysis commands reveal the PCs on which the PLC and HMI are running and their communication protocols. Figure 8 shows the port scan results on a PC running the OpenPLC runtime. The results show that the PC has open ssh and Modbus/TCP ports.



```
Nmap done: 17 IP addresses (11 hosts up) scanned in 209.69 seconds
(base) satoru@MacBookPro16 ~ % sudo nmap -p10-1000 192.168.10.2
Starting Nmap 7.91 ( https://nmap.org ) at 2021-02-24 12:50 JST
Nmap scan report for 192.168.10.2
Host is up (0.0074s latency).
Not shown: 989 closed ports
PORT    STATE SERVICE
22/tcp  open  ssh
502/tcp open  mbap
MAC Address: B8:27:EB:CA:2E:A5 (Raspberry Pi Foundation)
```

Figure 8 Port Scan Result

(b) Man-In-The-Middle attack

A man-in-the-middle attack is a cyber attack in which a malicious attacker intrudes into a conversation between two parties, impersonating both parties and gaining access to information that the two parties intended to share. Figure 11 shows man in the middle attack model. The malicious attacker intercepts and transmits data intended for the other party or never intended to be transmitted without the outside party being aware of it until it is too late. The attacker launches a man-in-the-middle attack between the PLC and the HMI, intercepting communications between the PLC and the HMI and acquiring PLC control commands and sensor data without the operator being aware.

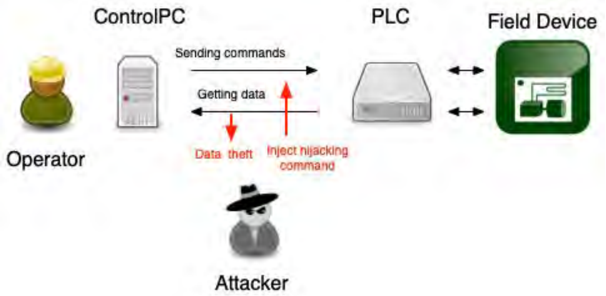
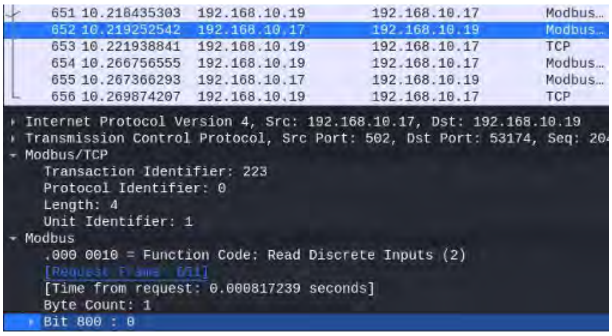


Figure 9 Man in the Middle Attack Model

(c) Modbus/TCP attack

Modbus packets have a function code that specifies the type of operation requested. All Modbus devices have a register map of functions used to monitor, configure, and control the input/output of the module. The Modbus/TCP protocol is an extension of Modbus Serial to TCP/IP communication, with features such as encryption and authentication. It does not have encryption and authentication. Figure 10 shows a packet-captured Modbus communication.

Therefore, ICSs controlled by the Modbus/TCP protocol are vulnerable to cyber-attacks. The ICS is hijacked from intercepted Modbus/TCP communications in this scenario.



```
651 10.218435303  192.168.10.19       192.168.10.17       Modbus…
652 10.219252542  192.168.10.17       192.168.10.19       Modbus…
653 10.221938841  192.168.10.19       192.168.10.17       TCP
654 10.266756555  192.168.10.19       192.168.10.17       Modbus…
655 10.267366293  192.168.10.17       192.168.10.19       Modbus…
656 10.269874207  192.168.10.19       192.168.10.17       TCP
▸ Internet Protocol Version 4, Src: 192.168.10.17, Dst: 192.168.10.19
▸ Transmission Control Protocol, Src Port: 502, Dst Port: 53174, Seq: 20
▾ Modbus/TCP
    Transaction Identifier: 223
    Protocol Identifier: 0
    Length: 4
    Unit Identifier: 1
▾ Modbus
    .000 0010 = Function Code: Read Discrete Inputs (2)
    [Request Frame: 651]
    [Time from request: 0.000817239 seconds]
    Byte Count: 1
  ▸ Bit 800 : 0
```

Figure 10 Part of Packet Capture by Wireshark

Practicing the developed materials

A lecture using the developed teaching materials was conducted in the Robotics Systems Control Engineering course at the National Institute of Technology, Kochi College. The students who attended this lecture were electrical, electronic, and mechanical students who did not specialize in information engineering. The lecture included network reconnaissance and an attack using a vulnerability in the Modbus protocol.

Figure 11 Lecture using developed teaching materials

The following are some comments from the students who attended the lecture.

I could understand the advantages and dangers of connecting ICS to an open network.

I understood the necessity for electrical and mechanical engineers to know the terms related to networking.

This lecture was presented at the K-SEC public lecture event.

Conclusions

This paper reports constructing a cyber range in an industrial control system using OpenPLC, an open source software. This system can connect field devices used, and students can learn about the threat of cyber-attacks in real space.

The advantage of this material is that it is composed entirely of open source software, making it vendor-independent and inexpensive. On the other hand, frequent version upgrades of OpenPLC and Node-RED require revision of the Cyber Range Construction Manual.

We want to expand the Cyber Range by using this material in technical colleges and referring to their feedback.

Acknowledgments

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THE SUSTAINABILITY OF VIRTUAL LABORATORIES IN THE POST-COVID-19 ERA: IMPLICATIONS FOR RESILIENCE STRATEGIES TO PROMOTE STUDENTS' LEARNING EFFECTIVENESS

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Abstract

The COVID-19 pandemic has caused significant disruptions to the traditional delivery of engineering education, as institutions and universities were forced to move to online and hybrid formats to prevent the spread of the virus. During the pandemic, the use of virtual laboratories replaced physical laboratories to a certain extent in supporting the learning process in most institutions. Therefore, laboratory work is one of the certain face-to-face activities that cannot be easily replaced by a virtual approach. In view of the end of COVID-19 in sight, this shift to a virtual approach has presented a question for educators to understand the sustainability of virtual laboratories in the post-COVID-19 era and how virtual laboratories can be effectively integrated into the curriculum for future teaching and learning development. This research used a quantitative data collection method (i.e. a teacher survey; N=22) to evaluate the eight potential sustainability strategies that addressed the three main research questions. According to the research, the views on whether virtual laboratories can generate positive impacts on the quality of education and learning objectives of their courses during the COVID-19 pandemic were diversified. Results showed that the possibility of virtual laboratories opens up new perspectives for higher education sustainability, however engineering teachers preferred maintaining the current use of virtual laboratories rather than optimising this educational approach. Reactive measures instead of proactive measures were considered more attractive for teachers in attaining sustainability of virtual laboratories in the post-covid-19 era. Resilience strategies that focus on maintaining positive outcomes and reducing negative impacts shall be in place to promote students' learning effectiveness.

Keywords: *virtual laboratory; science and engineering; higher education; sustainability; resilience.*

Introduction

Laboratory experience is a key factor in technical and engineering education and laboratories are important environments for student learning. Practical works are critical to the learning process in science and engineering education. Science and technology education is based on the students' experimentation in a laboratory, where theoretical models are confirmed, and the teaching is given a practical orientation (Cabedo et al., 2018). They are an important and integral part of hands-on experience for science and engineering students which provide a better understanding of the theoretical concepts learned in classrooms.

In Hong Kong, with the outbreak of COVID-19 in early 2020, most of, if not all, the face-to-face laboratories were suspended and replaced by non-traditional or simulation laboratories. The latest technological advancements provided great opportunities for institutes to go over geographic and time restrictions using 3D virtual learning environments that support simulations and observations of various experiments. However, certain face-to-face activities such as laboratory work cannot be easily replaced by online mode, according to a perception study on microbiology laboratory sessions (Joji et al., 2022). Although the high success rate of virtual laboratories in institutions of education and training was noted (Azad, 2007), there is an increasing concern about the sustainability of these virtual laboratories across the higher education sector. As such, this research aims to answer the following research questions:

- What is the role of virtual laboratories in post-COVID for engineering education?
- How do engineering teachers perceive the future use of virtual laboratories in their teaching after COVID-19?
- How can virtual laboratories be effectively integrated into the curriculum to enhance student learning outcomes?

Background

Virtual laboratories have been proposed to students with less popularity before the COVID-19 pandemic. Home laboratory kits were adopted by oversea institutions such that students could conduct real experiments at home (Tan et al., 2019). Students were required to come back to the institution for collection and the number of laboratory kits was great for large class sizes. Therefore, the types of experiments that can be done at home were limited due to complexity and safety concerns.

During the COVID-19 pandemic, the learning and teaching of science and engineering subjects faced a big challenge because all face-to-face laboratory work was suspended. Since laboratory works were essential and critical elements of science and engineering education. Teachers tried other means to relieve the effect by performing a demonstration, simulation or virtual laboratory, such that experimental data can be collected for analysis afterwards. However, students commented that they cannot see and control the laboratory apparatus in "real" time. Hence, a virtual laboratory approach for engineering education was proposed to facilitate student independent learning, enhance their learning experience, and solve the adverse effect created by the suspension of face-to-face laboratory work.

The COVID-19 pandemic has forced face-to-face laboratory work to be suspended. As a result, the demand for alternative delivery modes of the laboratory has increased significantly. In response, various virtual laboratories have been developed across different institutes to address these challenges. Since laboratory work plays a critical role in science and engineering education, teachers were using various methods to let students complete laboratory work at home instead of simply cancelling the laboratory work. While some teachers employed high-quality simulations or virtual laboratories, students who cannot have hands-on experience with real laboratory equipment and materials were criticized.

The Hong Kong Institute of Vocation Education (IVE) considers laboratory works are essential components of the Higher Diploma (HD) engineering programme and normally requires students to perform experiments in person. Apart from learning practical skills, through laboratories, students develop their ability to work in teams and problem-solve, by applying theory-based learning to real engineering problems.

In view of the end of COVID-19 in sight, it is necessary to explore how digital content in the physical world in real-time can be probably further developed for the maximized benefits to our students. Along with traditional laboratories, virtual laboratories have the potential to provide immersive and interactive learning experiences that can help students better understand complex engineering concepts and apply them in practical settings. Virtual laboratories may help to bridge the gap between theory and practice by contributing to the development of an effective pedagogical approach for the engineering field.

Literature Reviews

The importance of laboratory experience in engineering education (and other fields) has long been recognized (Grosh, 1967). Such experimental skills were considered crucial in the sciences as well as computer science (Tichy, 1998). Educational engineering labs present an essential part of engineering education because they provide practical knowledge for students.

Interacting with 3D objects from various angles and perspectives improved students' spatial abilities and technical skills (Cheng & Tsai, 2013; Kerawalla et al., 2006; Tuli et al., 2021). A study on Augmented Reality (AR)-based remote laboratories had shown that AR-based laboratories were effective in civil engineering and had been successfully designed and implemented with increased students' motivation, curiosity, in-depth understanding, and spatial interpretation (Shirazi & Behzadan, 2014).

Safety was another important concern when the laboratory apparatus was operating remotely and without the supervision of a technician and outside office hours (Tan et al., 2019). Hence, the virtual laboratory which adopted a fail-safe design can alleviate the complexity and safety concerns. For example, with the developed VR contents, students were able to experience and practice emergency operation procedures via role-plays in a safe environment. This also enabled students to put theory into practice and enriched their learning experiences so as to bring their talent into full play. Such "learning-by-doing" experience probably made learning more interesting, at the same time providing students with more practice to enhance the skill sets of problem-solving and decision-making (Perote, 2016), which were essential for working in the engineering industry.

In particular, there were three different categories of laboratories namely hands-on laboratories, simulated laboratories and remote laboratories. Every category of laboratories attempted to reach reality, as shown in Figure 1. Ma et al. (2006) gave details on hands-on, simulated, and remote laboratories in which the nature of equipment, devices and models were specified. Regarding the Reality-Virtuality Continuum as shown in Figure 2, the real world and the virtual environment were at the two opposite ends of this continuum with the middle region called Mixed Reality (MR) or even Extended Reality (XR) as proposed by Canizares (1997).

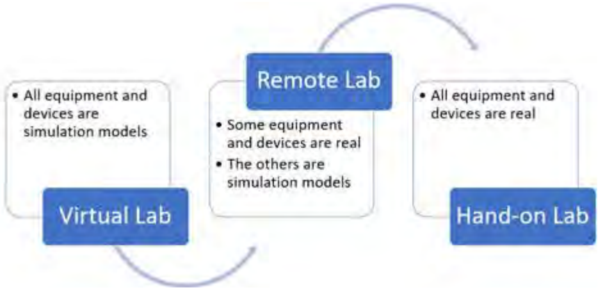

Figure 1. The realism of hands-on, remote and virtual laboratories

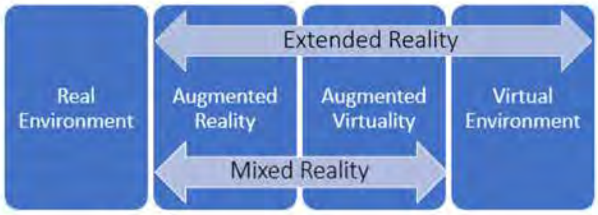

Figure 2. A simplification of the Reality-Virtuality Continuum consisting of MR and XR

Architecture

As one of the best alternatives against the cancellation of face-to-face laboratories, virtual laboratories were proposed to perform experiments remotely through a software interface by providing 3D visualization of the laboratory experiments (Figure 3) and allowing students to interact with the learning environments (Figure 4). Students can not only develop their independent learning ability but also experience participation throughout the laboratory (Figure 5). Moreover, virtual laboratories provide flexibility in learning to students without the support of technical staff by providing step-by-step instructions (Figure 6).

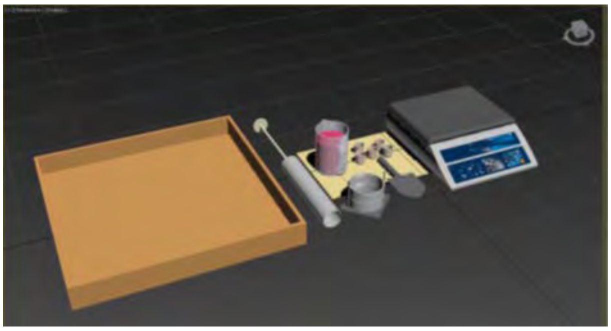

Figure 3. Descriptions of various apparatus were provided to better illustrate the setup.

Figure 4. A laboratory was animated with a presentation of streamlined procedures.

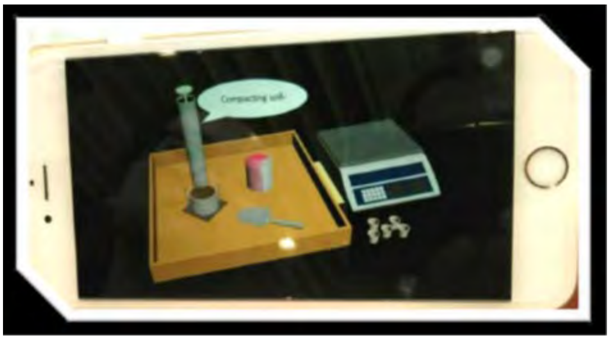

Figure 5. A virtual laboratory provided text instructions to students about the experiment.

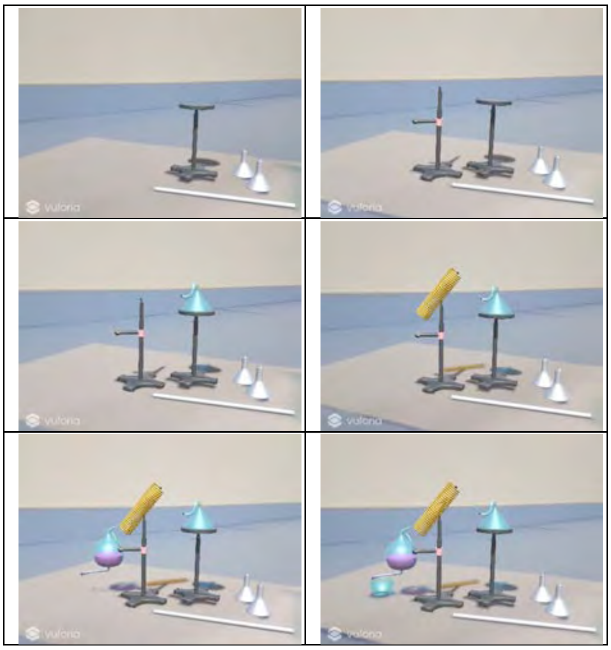

Figure 6. A virtual laboratory approach provides the opportunities for students to learn step-by-step.

Methodology

The research was rooted in a quantitative approach by using the online survey as the major data collection tool. The data was analysed based on teachers' feedback in the engineering discipline. The report aimed to provide findings and recommendations for the future use of virtual laboratories and their development by a reference to quantitative data obtained. Data were collected at the time of the end of COVID-19 in sight (i.e. February to March 2023).

The research methodology involves the evaluation of the survey based on 11 questions with different sections to teachers about their confidence in the sustainability of virtual laboratories and their views on relevant resilience strategies. Eight (8) potential sustainability strategies were proposed in this research to investigate the feasibility of various measures or mechanisms to overcome challenges in the further application of virtual laboratories. The following potential sustainability strategies were included:

1. Integrating virtual labs into the curriculum to enhance the learning experience of students

2. Ensuring the quality and effectiveness of virtual labs in the long term
3. Encouraging faculty members to promote the use of virtual labs and support students in their use
4. Mitigating potential risks and challenges associated with the sustainability of virtual labs
5. Providing continuous support and extension of virtual labs with additional resources and budget
6. Enforcing compulsory enrolment for students in virtual labs
7. Sharing of the virtual labs with other programmes through further developed content that fit their teaching needs
8. Collaborating with other institutes and industrial practitioners through sharing and external participation

The report focused mainly on the teachers' perspectives and the data collected was a snapshot of a period without reference to any historical data, this can serve as reference information for general, indicative and reference purposes only.

Results

A total of twenty-two (N=22) engineering teachers from various departments participated in the survey. When asked about their perception of virtual laboratories, 55% of the respondents agreed that virtual laboratories can provide a valuable addition to the quality of education during the COVID-19 pandemic (Table 1). Moreover, 68% of the respondents agreed that virtual laboratories can provide students with the necessary skills and knowledge to meet the learning objectives of their courses during the COVID-19 pandemic (Table 2).

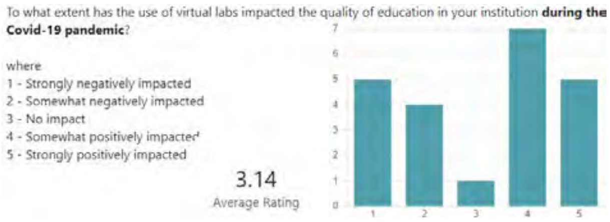

Table 1. Results on the use of virtual labs impacted the quality of education in your institution during the COVID-19 pandemic.

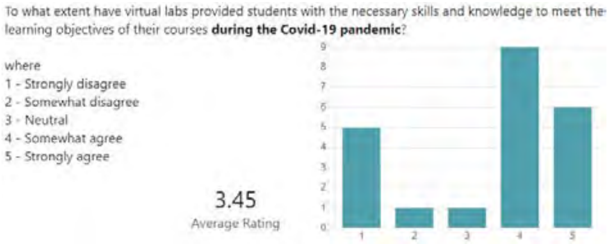

Table 2. Results of virtual labs provided students with the necessary skills and knowledge to meet the learning objectives of their courses during the COVID-19 pandemic.

Without further resource implication in the post-COVID-19 era, the survey results indicated a positive perception of virtual laboratories for the four potential sustainability strategies among engineering teachers. "Encouraging faculty members to promote the use of virtual labs and support students in their use" and "Mitigating potential risks and challenges associated with the sustainability of virtual labs" were more acceptable measures than "Integrating virtual labs into the curriculum to enhance the learning experience of students" and "Ensuring the quality and effectiveness of virtual labs in the long term". For details, Table 3 gives the breakdown.

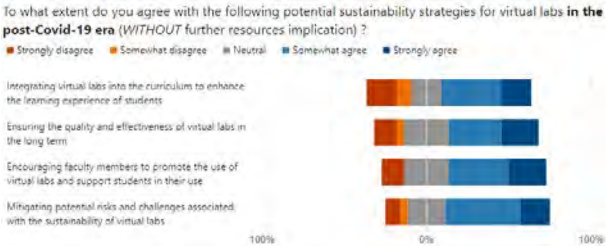

Table 3. Results on potential sustainability strategies for virtual labs in the post-Covid-19 era (without further resources implication)

With further resources implication in the post-COVID-19 era, the survey results indicated a positive perception of virtual laboratories for the four potential sustainability strategies among engineering teachers. "Providing continuous support and extension of virtual labs with additional resources and budget" and "Collaborating with other institutes and industrial practitioners through sharing and external participation" were more acceptable measures than that "Enforcing compulsory enrolment for students in virtual labs" and "Sharing of the virtual labs with other programmes through further developed contents that fit their teaching needs". For details, Table 4 gives the breakdown.

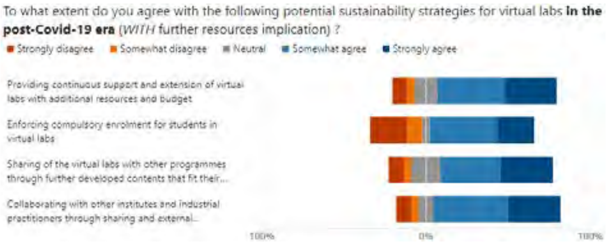

Table 4. Results on potential sustainability strategies for virtual labs in the post-Covid-19 era (with further resources implication)

Overall, the majority of the respondents agreed that some of the proposed potential sustainability strategies for virtual laboratories can generate positive learning outcomes and improve student engagement and motivation.

Discussion

According to the research, the views on whether virtual laboratories can generate positive impacts on the quality of education and learning objectives of their courses during the COVID-19 pandemic were diversified. Virtual laboratory resources can be shared among a large community to geographically distributed users with limited setup and operational costs. While virtual laboratories are beneficial from an economic and organizational point of view, it is not clear that they can remain sustainable in the post-covid-19 era. In the case that virtual laboratories will be further developed, resilience strategies for the future use of virtual laboratories must be formulated to promote students' learning effectiveness and the sustainability of these educational approaches.

Firstly, providing resources for teachers to support the use of virtual laboratories in their teaching can be important for increasing access and promoting sustainability. With further resources implication in the post-COVID-19 era, the use of virtual laboratories was demotivated among engineering teachers. Teachers were dissatisfied and unmotivated by an educational goal to make “optimization”. On the other hand, teachers were more satisfied and motivated to employ virtual laboratories if this approach was intended for the “maintenance” of what we had. We modified Herzberg’s Motivation-Hygiene Theory (Herzberg, 2005) to depict how our proposed potential sustainability strategies influenced the teachers’ dissatisfaction and satisfaction through the analysis of hygiene factors and motivator factors, of which they acted independently of each other. We found that ranked in order of priority, a) mitigation measures, b) encouragement measures, c) collaboration measures, d) supporting mechanism, and e) sharing mechanism facilitated teachers’ satisfaction and motivation because they focused on maintaining positive outcomes and reducing negative impacts. Comparatively, we found that, ranked in order of priority, a) actions for integration, b) quality assurance and c) compliance mechanism which focused on optimizing systems and outcomes dissatisfied and unmotivated teachers to use virtual laboratories. For details, readers are recommended to refer to Figure 7.

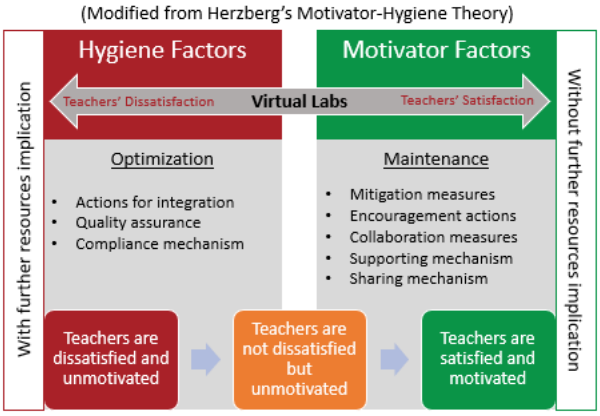

Figure 7. Teachers’ dissatisfaction and satisfaction spectrum over the use of virtual laboratories based on Herzberg’s Motivation-Hygiene Theory

The survey also revealed some of the challenges in promoting virtual laboratories for further use. The most common challenge reported by the respondents was the limitations of virtual laboratories in replicating the physical laboratory experience. Another challenge reported was the reluctance to deploy further resources for the development of quality virtual laboratories. A minority of the respondents disagreed that virtual laboratories can be effective in teaching engineering concepts at all.

Conclusions

The pandemic has principally changed the way the higher education sector operates. It has caused a profound shift in how we conduct our teaching, with a large-scale take-up of remote teaching and changes in our digital approach. Among these changes, virtual laboratories were proposed to minizine negative effects on science and engineering teaching and learning as an innovative pedagogical approach at the IVE in Hong Kong.

In post-COVID for engineering education, the further use of virtual laboratories would be uncertain. With the ongoing pandemic, traditional laboratory sessions have become challenging due to physical distancing requirements and limited access to equipment. It is true that virtual laboratories can provide a temporary solution to this problem by allowing students to conduct experiments and practice engineering skills in a simulated environment. However, this technology was also questioned for its ability to expand access to laboratory experiences due to an inadequate level of resource commitment. Engineering teachers perceived the future use of virtual laboratories in their teaching as a dispensable addition to their laboratory work.

Many teachers considered that maintenance of using virtual laboratories out of its current abilities was a preferred option rather than that of optimization of virtual laboratories. Obviously, some teachers may still prefer traditional laboratory sessions, as they provide a more hands-on experience and allow for more interaction between students and instructors.

To effectively sustain virtual laboratories in further use and into the curriculum, if required, institutions should consider the following recommendations. The first essential issue is to provide clear instructions and guidelines for using virtual laboratories. The second issue is to clearly define the use of virtual laboratories to supplement traditional laboratory sessions, but not to replace them entirely. Lastly, it is important to observe feedback from students and teachers before integrating virtual laboratories into the curriculum. By doing so, there is a higher chance of success for virtual laboratories that can not only enhance student learning outcomes by providing a safe and accessible environment for experimentation but also promote active learning by improving student engagement and motivation.

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A Matterport-based Integrated Virtual Laboratory Environment for Engineering Students

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Abstract

Given the emergence of technological advancements like the Internet of Things (IoT), Artificial Intelligence, Augmented and Virtual Reality, it is imperative for engineering education to keep up with industry demands. To achieve this, one promising approach is the utilization of virtual labs. These labs provide students with practical training in a simulated environment, which enables them to acquire hands-on experience. In this paper, the authors proposed the use of Matterport, a 3D camera and virtual tour platform, to create a virtual lab environment for Year 1 Engineering students in Ngee Ann Polytechnic. Matterport's ability to create highly detailed and accurate 3D models of physical spaces makes it an ideal tool for building virtual labs. More specifically, a virtual environment of a Thermofluid lab was created, focusing on the perfect gas expansion equipment. The lab equipment in the virtual environment was furnished with instructional videos and simulation data to enhance interactivity.

The virtual environment provides students with access to the perfect gas expansion experiment and offers the advantage of enabling students to conduct "risky" experiments such as gas expansion without any danger. Additionally, the virtual lab and its equipment are available 24/7, which provides opportunities for students to practice and learn at their own pace and time. This benefit was particularly valuable during the campus closure due to the COVID pandemic. Another advantage of virtual labs is that they reduce the need for physical space and associated equipment maintenance.

The Matterport virtual lab was used as a substitute for in-person instructor-led lab for peri-corona home-based learning and as a supplementary learning resource for post-corona hybrid learning. To evaluate the efficacy of the Matterport virtual lab, the authors conducted a comparative analysis of students' laboratory performance results for three different semesters (pre-corona, peri-corona, and post-corona periods) involving cohorts of 400 students each. There was only a 4.3% deviation in the mean and median laboratory scores between the pre-corona and peri-corona results, indicating that students achieved similar learning outcomes and competencies while completing the perfect gas experiment solely through the virtual lab during peri-corona as compared to in-person instructor-led lab during pre-corona. Based on the same metrics, it was also observed that the post-corona results showed a 7.36% improvement compared to pre-corona results. This suggests that students were able to effectively use the virtual lab as a supplementary learning resource to enhance their learning. Furthermore, an evaluation survey conducted with the students revealed that on average, each student spent an extra 28.5 minutes on the virtual lab in addition to the 1-hour instructor-led experiment weekly. The 47.5% increase in time spent by each student in the lab during post-corona as compared to pre-corona may have contributed to the observed improvement in grades. These findings indicate that virtual labs have the potential to be an effective and efficient alternative to traditional face-to-face labs. Additionally, they serve as a flipped learning and recap tool that extends students' learning, thus offering possibilities for enhancing engineering education.

Keywords: *Engineering education, virtual labs, Matterport, 3D camera, virtual tour platform, simulated environment, Thermofluid lab, perfect gas expansion equipment, post-corona era.*

Introduction

The global COVID-19 pandemic has disrupted conventional education practices, including laboratory-based engineering learning. The implementation of physical distancing measures and the shift towards remote or online learning by many educational institutions has limited students' access to traditional laboratory facilities. As a result, there is a growing demand for virtual lab environments that can replicate hands-on learning experiences while ensuring safety and accessibility. Various technologies, such as Matterport (Rauch et al, 2021), Labster (Shady et al, 2021), and Virtual Lab, can be employed to create digital models of physical spaces for virtual lab simulations. Jeschke et al. (2007) have demonstrated that these virtual lab environments enable students to virtually tour real-world engineering projects or sites, facilitating exploration and analysis of designs and structures in ways that were not possible through traditional methods, such as photographs or drawings. Furthermore, to stay relevant and competitive in the rapidly evolving technological landscape, it is crucial for engineering education to remain up to date with emerging industry trends. With advancements like the Internet of Things (IoT), Artificial Intelligence (AI), and Augmented and Virtual Reality (AR/VR), it is imperative that students are adequately prepared to meet the demands of the modern workplace. To achieve this, one approach is to provide students with practical experience working with these technologies through simulated environments such as virtual labs. This can equip students with the necessary skills and knowledge to excel in their careers and contribute to the advancement of these fields. The aim is to ensure that graduates are well-equipped to handle the challenges of the industry and stay up to date with emerging trends.

Literature Review

Studies have shown that the use of virtual labs, created with Matterport or similar, can be an effective way to enhance student learning and engagement in engineering education. For example, Baher J. (1998) implemented CyclePad, a versatile virtual lab, in thermodynamics courses across three schools. Students reported improved understanding of thermodynamics, acquisition of problem-solving techniques, and ease in performing calculations through the use of CyclePad. Instructors could assign more realistic problems compared to traditional textbook exercises. Similarly, Chu K. C. (1999) found that virtual labs save time and help students learn basic and advanced concepts through remote experimentation. As the adoption of virtual labs has increased, recent technology tools have been developed to enhance the immersive learning experience. For instance, Cave Automatic Virtual Environments (CAVE) and Head Mount Displays (HMD) described by Freina et al. (2015) are considered expensive and not easily available to many students. Therefore, Robertson et al. (1993) introduced non-immersive VR (Virtual Reality), which places the user in a 3D environment behind a conventional graphics workstation, while providing the user with the ability to interact with the 3D environment through various audiovisuals. Non-immersive VR can be captured by 360 cameras, which have become affordable to the consumer market in recent years, as mentioned by Wolf et al. (2021). Matterport, a 3D scanning technology, is one of such platforms which can be used to provide such non-immersive VR experience. It was originally developed for the real estate industry, but it has found its innovation footing in education. In engineering education, it can provide students with virtual tours of real-world engineering projects or sites, engineering workplaces, and labs. This enables them to explore and analyze designs and structures that are richer in content than traditional methods such as photographs or drawings. In this paper we shall consider its application in the development of a virtual lab. The incorporation of virtual labs into engineering education has the potential to enhance student engagement, deepen understanding of concepts and principles, provide cost-effective access to real-world engineering projects without the need for costly field trips, and promote safety through simulation of scenarios when safety is not adhered to. For instance, Bell and Fogler (2004) applied virtual reality (VR) to chemical engineering education and highlighted the consequences of improper safety procedures in a controlled virtual environment.

Development and Implementation

Development of 3D Matterport virtual lab

The initial step in developing the virtual laboratory involved identifying a suitable physical experiment for converting it to virtual experiment. Given the study's preliminary nature, the experiment's simplicity was a key consideration in selecting suitable experiments to be converted to virtual experiments. Consequently, the isothermal gas expansion lab was chosen due to its straightforward equipment setup and the fact that only 50% of the drawn conclusion requires the collection of experimental data, with the remaining portion relying on theoretical calculations. The objective of the isothermal gas expansion lab is to investigate and validate the Characteristic Gas equation. Students are tasked with recording initial and final pressure and temperature values of a chamber which undergoes a pressurized air expansion. The final pressure and temperature values will serve as the experimental results which shall be compared alongside a theoretical set of results. The theoretical set of results is calculated by utilizing the Characteristic Gas equation (1) with the initial pressure and temperature as inputs. The expected result of this experiment includes a deviation between the experimental and theoretical results which requires the students to comment on the effect of irreversibility during the expansion process which contributed to the deviation.

$$pV = mRT \qquad (1)$$

Where,
p: Pressure (Pa)
V: Volume (m^3)
m: Mass (kg)
R: Gas constant (J/kgK)
T: Temperature (K)

To create an immersive virtual lab, the Matterport Pro2 3D Camera proves to be an invaluable tool. With its high-quality 4K resolution capture and cutting-edge infrared technology, it allows for detailed scanning of an engineering lab (Figure 1). The resulting virtual lab (Figure 2) provides students with remote access and exploration of the equipment and experiments in unprecedented ways that traditional methods such as photographs or drawings simply cannot replicate. The Matterport Pro2 3D Camera offers some key features that enhance the virtual lab experience. Its 360° views and spherical images enable students to view the lab from all angles, providing a truly immersive experience. The automated generation of color 2D and 3D interactive floor plans adds a new dimension to understanding the lab layout and equipment placement. The camera captures 3D scans with remarkable accuracy, ensuring that the virtual lab is an accurate representation of the real-world lab.

Figure 1:Matterport 3D camera scanning

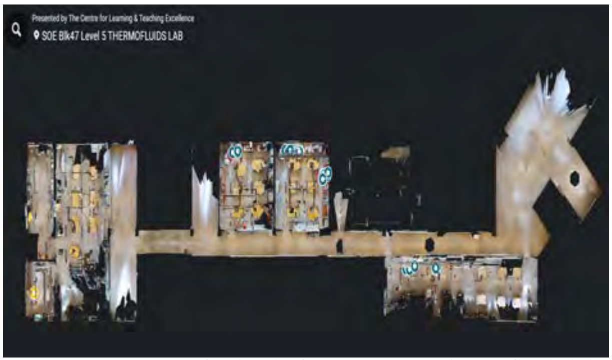
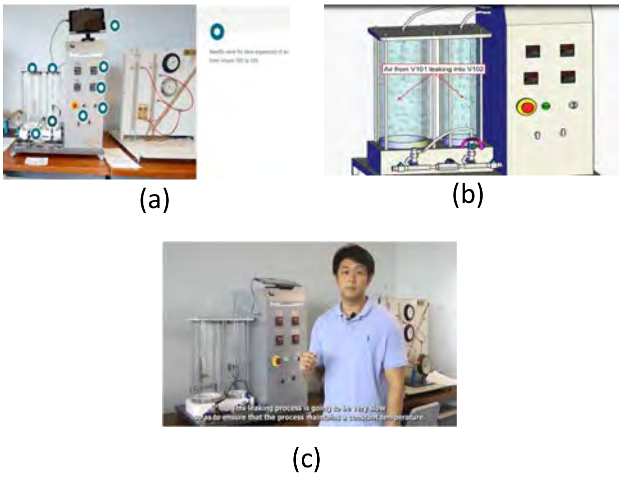


Figure 2: 3D scan of School of Engineering Thermofluids lab

Other than providing a digital replica of the lab, the Matterport platform also allows for a more interactive form of learning. One feature is the ability for learners to perform annotations on the equipment in the virtual environment. These annotations allow them to understand the uses and functionality of each part of the equipment.

Videos can also be embedded within the environment to enhance the learning experience. For the isothermal experiment presented in this paper, two sets of instructor-led teaching videos and one set of simulation results were embedded within the environment. The teaching videos provide students with visual and auditory explanations of the equipment and perfect gas theory used in the experiment. In the era of post-corona hybrid learning, where students have access to both digital and physical platforms of learning, such videos can be particularly useful for students who learn more effectively through visual aids, and students can also replay them to capture relevant information that might have been missed during the physical lesson. In addition, simulation results or visuals were obtained by simulating the isothermal expansion process using SolidWorks software. The simulation is particularly useful for this experiment as it allows learners to visualize how the air particles expand from the pressurized chamber to the occupy the secondary chamber, which would be impossible in a real-life demonstration as air molecules are invisible to the naked eye. The simulation results also enable students to see the predicted outcomes of the experiment and compare them with their own results, helping them to identify and correct any errors in their experimental setup. This allows for a deeper understanding of the experimental procedure and the underlying thermodynamic principles of the isothermal expansion process



(a) (b)

(c)

Figure 3: Features of the virtual lab- (a)Equipment annotation; (b)Simulation; (c) Instructional video

Implementation of 3D Matterport virtual lab

The virtual lab was initially implemented during the peri-Covid period when students were not allowed to return to campus to perform experiments due to the movement control order. With the virtual lab, students were able to access a "life-like" laboratory environment from the safety and comfort of their homes and collected experimental data through the virtual platform, successfully fulfilling academic requirements for their diploma. After the pandemic ended and students were allowed to return to campus, Ngee Ann Polytechnic saw an opportunity to transition its teaching and learning practices from traditional delivery methods to a hybrid approach. One of the major initiatives was the rollout of Online Asynchronous Learning (OAL) for all modules, which is part of a flipped learning pedagogy. The OAL requires students to go through a set of learning activities and videos related to the teaching topic before coming to class. This achieves greater efficiency and effectiveness in terms of face-to-face delivery as students gain foundational knowledge before coming to class, and class sessions can be used to deepen their learning on advanced concepts. With its self-directed and asynchronous learning characteristics, the virtual lab was integrated into the OAL content, providing students with an overview of the lab before attending the physical laboratory sessions. Thus, in the post-Covid period, the virtual lab was successfully deployed as a self-directed flipped learning tool as part of the OAL content, supplementing students' learning in class.

Results and Discussion

The analysis of results will be divided into two subparts to examine the effectiveness of the virtual lab in supporting engineering students to complete the perfect gas experiment and its ability to serve as a learning enhancement tool as the school pivots towards post-corona hybrid form of learning. In the first part, the results of a student survey are analyzed to evaluate the effectiveness of the virtual lab as a tool for teaching engineering concepts during the peri-corona and post-corona periods. In addition, individual response and feedback on the virtual lab are examined to sieve out key improvements to be made to future iterations of the virtual lab. The second part of the results analysis will focus on the comparison between three different semesters of students' laboratory performance results across 3 different periods: pre-, peri- and post-corona. This comparative study aims to assess the virtual lab's ability to serve as a learning enhancement tool.

Student Survey

The student survey was conducted during the peri- and post-corona periods. The goal of the peri-corona survey was to examine the effectiveness of the virtual lab as an alternative replacement of the physical lab. However, the goal of the post-corona survey was to examine the virtual lab's ability to serve as a learning enhancement tool. The peri-corona survey consisted of one multiple choice question and three Likert scale questions; this survey was posted to a respondent group of 60 students. The results of the peri-corona survey are summarized in Figure 4 and Figure 5.

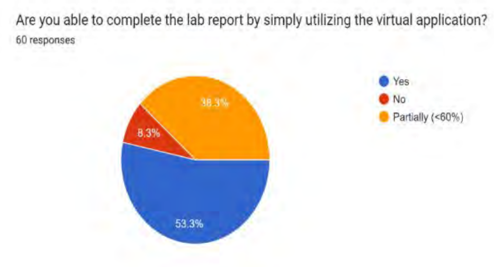


Figure 4: Peri-corona binary question

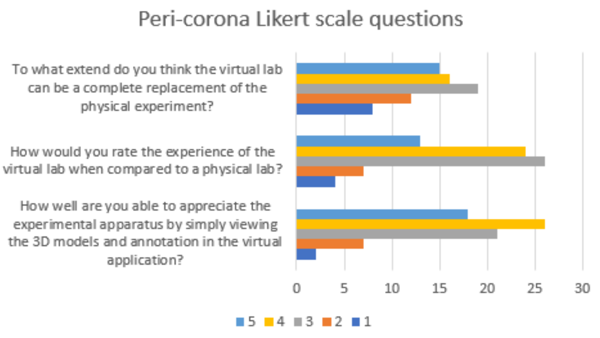


Figure 5: Peri-corona Likert scale questions

Responding to the question on whether the students were able to complete the Perfect Gas Experiment by utilizing the virtual lab alone, 8.3% gave a definite no, 38.3% mentioned that they were able to complete at least 60% of the lab while 53.3% was able to complete the lab work entirely. The "No" option represents students who were entirely not able to do the lab with the information provided by the virtual lab alone while "Yes" indicates that the student is able to complete 100% of the lab sheet by using the virtual lab alone. With regards to the Likert scale questions, where a rating of 5 meant that the student strongly agree to the statement and a rating of 1 indicate a strong disagreement, a median score of 3.08 was achieved when the students were asked if the virtual lab could serve as a complete replacement for the physical lab; a median score of 3.47 was recorded when the students were asked to rate their experience with the virtual lab as compared to a physical lab and a median score of 3.68 was achieved when it comes to understanding the use and application of the lab equipment in virtual formats. Overall, these results indicated a positive acceptance towards the virtual lab and thus, highlights that the virtual lab was effective as a teaching tool during the corona period in which face-to-face delivery teaching methods were restricted.

The post-corona survey consisted of two binary ("yes" or "no") questions, one Likert scale question (the 1-5 scale is defined the same way as in the peri-corona survey) and one multiple choice question; which was posted to a respondent group of 60 students. The results of the post-corona survey are summarized in **Error! Reference source not found.** and **Error! Reference source not found.** .

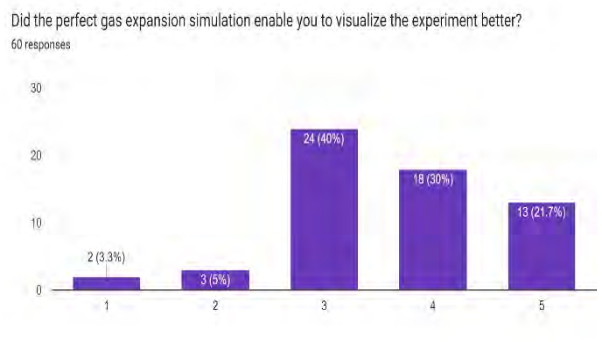


Figure 6:Post-corona Likert scale question

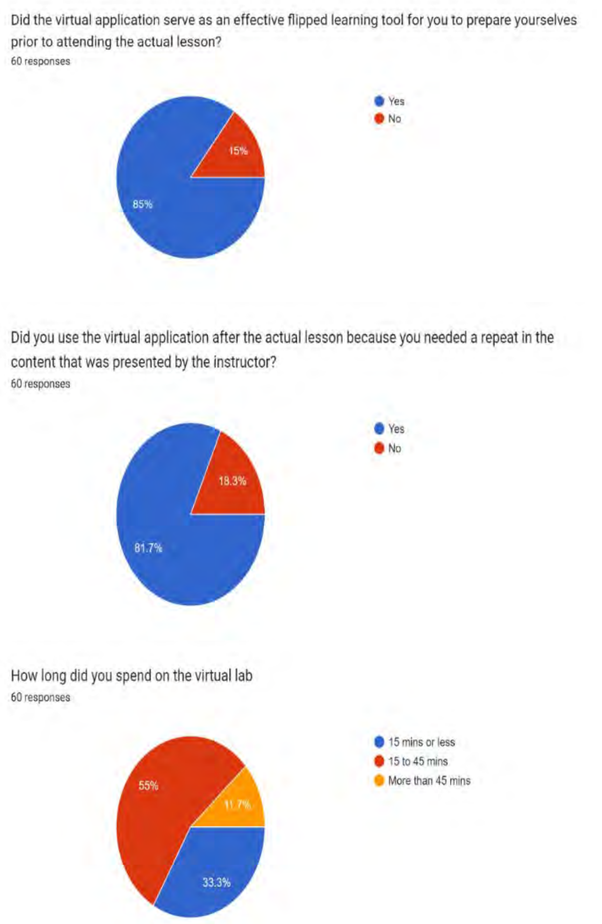


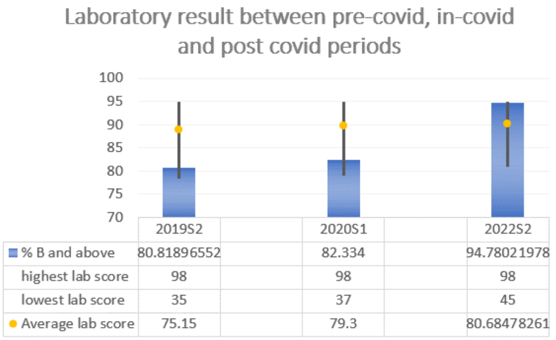
Figure 7:Post-corona survey (binary and multiple choice) questions

Based on the findings extracted from the post-corona survey, a noteworthy observation emerges. Specifically, a significant majority of 85% of the surveyed students expressed that the virtual application, when employed as a flipped learning tool, effectively aided them in preparing for the subsequent in-person lesson. Furthermore, an impressive 81.7% of the students reported utilizing the virtual lab as a recapitulatory resource after the completion of the physical lesson. These compelling results serve to validate the efficacy of the virtual lab as a suitable tool for augmenting students' learning experiences, while also serving as a supplementary resource to traditional face-to-face instructor-led laboratories.

On top of the structured survey responses, open-ended questions were also posted to the students to seek their direct feedback and opinion on the virtual lab. The student responses highlighted several areas for improvement in the virtual lab. These include addressing issues related to lag and connectivity, enhancing the sensitivity (to user inputs) of the virtual lab, providing heads-up for upcoming experiments or work, improving clarity of instructions and explanations, supplementing with more information such as videos, equations, and instructions, offering a feature to ask questions or seek clarification during the virtual lab, and ensuring a convenient and straightforward user experience. Furthermore, students emphasized that physical labs are still preferred for real-life exposure and hands-on interaction with apparatus, and that the virtual lab can serve as a supplemental resource for reference and reinforcement of learning. Overall, the feedback suggests the need for continuous improvement in the virtual lab to enhance its usability, interactivity, and effectiveness as a learning tool.

Semester on semester laboratory comparison

To evaluate the efficacy of the Matterport virtual lab as a substitute for face-to-face instructor-led laboratory experiments and as an enhancement tool for post-corona hybrid learning, we conducted a comparative analysis of laboratory results for three different semesters involving cohorts of 400 students each. The analysis was conducted for pre-, peri- and post-corona periods. We found a 4.3% deviation in the mean and median laboratory scores between the pre- and peri-corona results, indicating that students achieved similar learning outcomes and competencies while completing the perfect gas experiment solely either through the virtual lab (peri-corona) or physical lab (pre-corona). Subsequently, we examined the post- and pre-corona results using the same metrics and observed a 7.36% improvement of laboratory score during the post-corona period. This suggests that students effectively used the virtual lab as a supplement tool to enhance their learning. Furthermore, an evaluation survey conducted among the students during the post-corona period revealed that on average, each student spent an additional 28.5 minutes on the virtual lab in addition to the 1-hour instructor-led experiment weekly (Figure 7). The 47.5% increase in time spent by each student in the lab during post-corona as compared to pre-corona period may have contributed to the observed improvement in laboratory scores. Our findings indicate that virtual labs can be an effective and efficient alternative to traditional face-to-face laboratory experiments. Additionally, they serve as a flipped learning and recap tool that extends the student's learning time, thus significantly enhancing engineering education.



	2019S2	2020S1	2022S2
% B and above	80.81896552	82.334	94.78021978
highest lab score	98	98	98
lowest lab score	35	37	45
● Average lab score	75.15	79.3	80.68478261

Figure 8: Lab result comparison between pre-covid, peri-covid and post-covid periods

Conclusions

In conclusion, the use of virtual labs, such as Matterport, in engineering education has the potential to be an effective way to enhance student learning and engagement, especially during the challenging times of the COVID-19 pandemic. Virtual labs provide students with remote access to real-world engineering project sites, allowing them to explore and analyze designs and structures in ways that were not possible through traditional methods. The virtual lab created using Matterport technology has shown promising results in helping engineering students to complete the perfect gas experiment and gain a deeper understanding of the experimental process and underlying scientific principles. The results of the student survey indicated that the virtual lab was well-received by students, with positive feedback on its effectiveness in teaching engineering concepts. The ability to access the virtual lab remotely and at any time, the annotation feature for taking notes and observations, the embedded instructional videos, and the simulation results have contributed to a more engaging and immersive learning experience. Furthermore, the comparison of laboratory results across different periods, which are pre-, peri-, and post-corona, suggests that the virtual lab can serve as a viable alternative to traditional laboratory work, especially in times when physical access to labs may be limited.

However, it is important to note that virtual labs should not be seen as a complete replacement for traditional laboratory experiences, as hands-on learning and practical skills are still essential in engineering education. Virtual labs should be used as complementary tools to enhance student learning and provide additional opportunities for exploration and analysis. Moreover, further improvements can be made to the virtual lab environment based on the feedback from students and instructors, such as incorporating more interactive features, expanding the range of experiments, and optimizing the user interface for better usability. Thus, virtual labs, such as Matterport, offer a valuable solution to the challenges faced by engineering education during the COVID-19 pandemic and beyond. They provide students with remote access to real-world engineering projects, promote engagement, and enhance understanding of engineering concepts. As technology advances, virtual labs can revolutionize engineering education by providing innovative and immersive learning experiences that complement traditional laboratory work.

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Engineering Education Delivered in a Game-based Virtual Environment

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Abstract

With the advent of technology and the internet, learners today have become more accustomed to interactive media and self-exploratory learning tools. As such, gamification and self-directed learning approaches can be attractive for learners due to the shift in the way they learn.

This paper presents an engineering simulation game built for a module called Thermofluids, offered to Year 1 Common Engineering students in Ngee Ann Polytechnic. The aim of the game is to uplift the teaching and learning of engineering concepts and principles particularly in the domain of Thermofluids by providing students with an engaging, interactive, and self-paced learning experience. The game was developed in-house using the Unity3D game engine that allows for the creation of interactive 3D simulations and games; designed for self-directed learning which permits students to begin at a level that they can understand to construct knowledge at their own pace. The player experiences the game from a first-person perspective and takes up an intern persona who works in a sci-fi themed factory. The gameplay requires the player to complete a series of lessons, tasks and quizzes related to the topic of water pumps and steam systems.

An initial small-scale study was undertaken to evaluate the efficacy of this learning approach, two methods were used: an evaluation survey of 200 students and a performance comparison between an experimental group (with exposure to the game) and a control group (with no exposure to the game) in their ability to answer a pump design exam question which requires students to apply their knowledge on sizing the pump to meet certain design specifications. A hypothetical p-test at a 5% significant value was conducted to compare the performance between these two groups. The probability was found to be less than 0.05, indicating convincing evidence that the experimental group's performance was significantly better than the control group, thus further supporting the hypothesis of the game being an effective reinforcement learning tool. In addition, the evaluation survey results showed that 70.5% of students agreed that they were able to understand the engineering concepts presented through the gameplay and 61.5% of students agreed that the game was effective in delivering the concepts to them. This study suggests that the use of gamification and self-directed learning pedagogy in simulation games can be an effective approach for enhancing engineering education.

Keywords: *Engineering simulation game, Gamification, Self-directed learning, Thermofluids, Unity3D, Interactive, Self-paced.*

Introduction

Today's students are digital natives who grew up with digital technology and have spent a significant amount of time interacting with computers, video games, and digital devices. This has caused them to think and process information differently than previous generations, having a more visual learning style and limited attention span. Integrating virtual game technology in engineering education can revolutionize the way students learn and perceive engineering. With the advancement of digital technology, students have grown accustomed to a more visual and interactive learning experience. Virtual games provide a dynamic and engaging platform for students to learn and apply engineering concepts, making the subject more attractive and accessible. Various literature such as Wiggins (2016) has highlighted the effectiveness and advantages of using games in education. These engaging games create a low-pressure environment for reviewing, testing, and refining ideas while addressing any misconceptions (Fuentes, Crown, & Freeman, 2008). Additionally, according to Sancho, Torrente, and Fernández-Manjón (2009) virtual games foster the development of soft skills that are highly sought after in the industry, such as communication, teamwork, and problem-solving. By providing an immersive and realistic learning environment, virtual games can bridge the gap between the traditional engineering academia and the evolving industry demands. Moreover, virtual games can help to keep pace with the rapid advancement of technology, allowing students to stay updated with the latest skills and knowledge. Therefore, the use of virtual games not only can make engineering courses more attractive (G. Barata et. al, 2013) but also help to mitigate problems such as decreasing enrollment in engineering programs and lack of creative thinkers among engineering graduates. With such benefits, Ngee Ann Polytechnic's School of Engineering has begun its early adoption of such virtual game in its engineering curriculum by building an engineering simulation game for a module called ThermoFluid, offered to Year 1 Common Engineering students. This paper shall provide details on the game development and presents the result of a small-scale study to evaluate the effectiveness of the game in enabling students to achieve better learning outcomes.

Literature

Developing games for engineering education can involve several different teaching pedagogies, depending on the specific goals and objectives of the game and the intended learning outcomes for the students. Problem-based learning (PBL) is a teaching method that involves giving students a real-world problem to solve and guiding them through the process of finding a solution. In the context of game development for engineering education, PBL could involve giving students a game design problem to solve, such as creating a game that teaches a specific engineering concept. Topalli and Cagiltay (2018) effectively implemented PBL through their real-life game development projects from scratch. Their results indicated significant improvement in student academic performance. Project-based learning (PjBL) is a teaching method that involves giving students a project to work on and guiding them through the process of completing the project. In the context of game development for engineering education, PjBL could involve giving students a project to create a game and guiding them through the process of designing and developing the game. Gamification is the process of using game design elements, such as rewards and points, to make non-game activities more engaging. In the context of engineering education, gamification could involve using game design elements to make learning engineering concepts more engaging and interactive. Gamification has demonstrated advantages in education, benefiting both teachers and students. These benefits, including enhanced engagement, motivation, confidence, attitude, learning perception, and performance, support the use of gamification in higher education (Subhash & Cudney, 2018). Collaborative learning is a teaching method that involves having students work together in small groups to complete a task or project. In the context of game development for engineering education, collaborative learning could involve having students work together in small teams to design and develop a game as shown by Arango et al (2007). Self-directed learning is a teaching method that encourages students to take responsibility for their own learning. In the context of game development for engineering education, self-directed learning could involve giving students the freedom to design and develop their own game and guiding them through the process of self-reflection and self-evaluation. It is interesting to note that many game developments combine multiple pedagogies in their game development such as the one shown by Villagrasa, Fonseca, Redondo and Duran (2014).

Design and Development

A methodical approach was employed to design the virtual game. The virtual game will be developed using Unity3D platform. Unity, a widely used game engine, is often used to create virtual environments for DGBL (Digital Game Based Learning) and assessment applications due to its key features like physics and building options, as well as its large user community. (Wang, 2018; Metallaoui et al, 2015; Nguyen et al, 2017). It is a real-time game development platform with a range of applications including gaming, manufacturing, cinematics, engineering, and architecture. It provides tools for creating multi-platform apps, including desktop, console, web, mobile, and VR/AR. The main development tool is the Unity Editor, which allows users to add game objects to the scene, such as characters, models, lighting, cameras, and audio effects. With the goal of enabling students to meet the learning objectives outlined in their diploma, these objectives were extracted and aligned accordingly. A generic storyline was then crafted as the foundation of the game. As the game was intended for Polytechnic Engineering students, who are players in the game, the storyline follows a fictitious engineering student completing an internship at a soda manufacturing company, thus providing familiar and relatable context for the player. The soda manufacturing plant is designed to incorporate learning elements related to thermodynamics and fluid mechanics. The schematic of the plant design is shown in Figure 1 and the actual setup in the game environment is shown in Figure 2 . Within the game, the player will need to go through a progressive increase in difficulty of task to help scaffold the learning process of the player. The entire game requires the player to perform 3 tasks which map to the recall (level 1), apply (level 2), and synthesize (level 3) skillsets under the main thinking skill framework (Su et al, 2011). The following segments will describe the game design in detail.

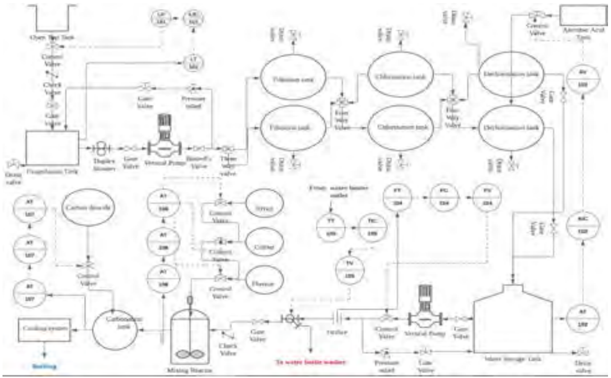

Figure 1: Design schematic of soda plant

Figure 2: Game environment

Fluid Mechanic Game Design

The Fluid Mechanic game design is divided into three parts and is designed to meet the following learning objectives:

1. Identify different types of pumps and describe their applications, with a focus on centrifugal pumps.
2. Interpret pump curves to obtain parameters for pump sizing.
3. Apply parallel and series pump configurations according to their intended functions.
4. Design and install a backup pump system in case of primary pump failure.

The first part is the competency building phase, where the student, playing the role of an engineering intern, learns about the fundamentals of pumps, pump types, pump curves, and pump installations. The student can complete interactive activities (Figure 3) and learn from the factory personnel during this phase. Once students have completed this phase, they can progress to the next level. In the second level, the student must install pumps in series and parallel configuration as a guided application of the knowledge they have acquired in part one. Upon successful completion of part two, they can move on to part three, where they are required to design and install a backup pump system in case of primary pump failure. If the students fail any part, they will be guided to repeat every part until they get it right.

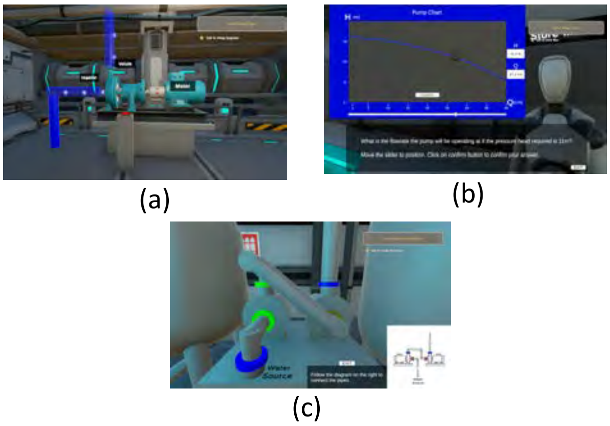
(a) (b)

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Figure 3 tasks a) Centrifugal pump configuration; b) Pump Curve; c) Parallel/Series pump

Thermodynamics Game Design

Similarly, the Thermodynamic game consists of 3 levels and is designed to meet the following learning objectives:

1. Describe the properties of steam and its application in a sterilization process.
2. Interpret steam tables.
3. Apply steady-state energy flow equations for heat exchanger sizing.

In level 1, the players must go through a series of interactive tasks which enables them to learn the fundamentals of steam and steam table. Level 2 involves a guided task of adjusting steam parameters to reduce energy consumption of the sterilization process which leads to cost reduction for the plant. After completion of level 1 and 2 tasks, the player will be presented with an advanced problem in which they need to design and implement a heat exchanger system to recover waste heat and reduce energy consumption. The level 3 task requires the player to utilize the same concepts learnt in level 1 and 2 to synthesize the solution and calculate the eventual cost savings and breakeven point of the heat exchanger. The schematic of the level 3 gameplay is shown in Figure 4. Each step taken to solve the level 3 problem is intentionally designed to meet certain subject knowledge (Table 1) so to ensure that the learning objectives of the Thermodynamic package are achieved

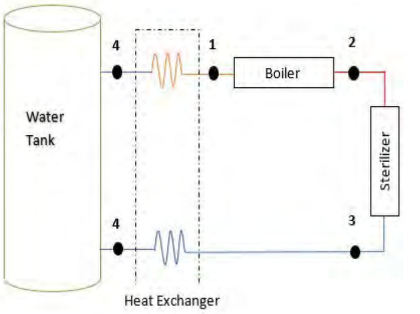

Figure 4: Schematic for heat recovery (level 3 gameplay)

Table 1 level 3 gameplay problem steps

Steps	***Subject knowledge***
• Student to check Saturated water and steam table, **<u>Conclude</u>** the steam from the sterilizer exit is wet steam.	*Use of Saturated water and steam table to determine state of fluid*
• Calculate h₃ using wet steam formula $h_3 = (1-x)h_f + xh_g$ $= (1-0.5) * 417 + 0.5 * (2675)$ $= 1546\ kJ/kg$	*-Use of wet steam formula to calculate enthalpy of wet steam*
• Obtain the new h_1' $Heat\ absorbed\ at\ the\ cold\ side = Heat\ lost\ at\ the\ hot\ side$ $\dot{Q_{in}} = \dot{Q_{out}} * hex\ efficiency$ $\dot{m}(h_1' - h_4) = \dot{m}(h_3 - h_4) * \varepsilon$ $0.3(h_1' - 108.9) = 0.3(1546 - 108.9) * 0.$ $h_1' = 1391.4\ kJ/kg$	*Demonstrate the use of Steady Flow Energy Equation* *Apply thermal efficiency of the heat exchanger*
• **<u>Calculate</u>** New Energy consumption = boiler heat input, $\dot{Q_{new}} = \dot{m}(h_{2,new} - h_1')$ $= 0.3 * (2707 - 1391.4)$ $= 394.68\ kW$	*Demonstrate the use of Steady Flow Energy Equation*
• **<u>Calculate</u>** energy savings, Energy Savings	*Conversion of kW to kWh*

$= 793.23\,kW * 12 * 30 - 394.68\,kW * 12 * 30 = 143478\,kWh$ $\%energy\ reduction = \frac{143478}{285562.8} * 100 = 50.2\%$ $Cost\ savings = 143478 * 0.3 = \$\,43043$	*Energy savings calculation* *Cost savings calculation*

Both games were developed within the same application and students can choose which game they wish to start with. Upon starting, each package is designed to be sequential, and the student can only be certified as completed when they have successfully solved all three parts. Figure 55 provides a clear overview of how the various parts of the game are connected and how the student can progress through the game.

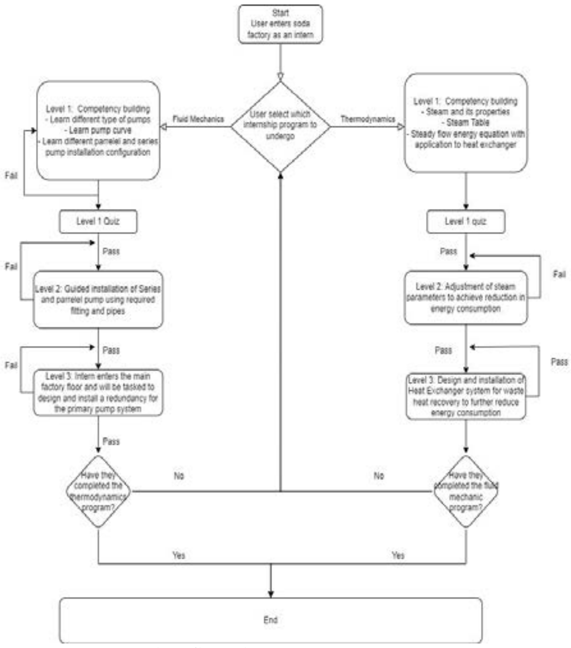

Figure 5: Gameplay flowchart

Results and Discussion

The effectiveness of the virtual game in supporting engineering students to learn ThermoFluid concepts and its impact on students' academic performance was examined in 3 ways. 1. Student survey, 2, Qualitative responses, 3. Control group study where students' performances in those that played the virtual games were reviewed against those that did not. In the first part, the quantitative results of a student survey will be discussed. This survey aimed to evaluate the effectiveness of the virtual game as a tool for teaching engineering concepts. The second part of this segment will focus on individual qualitative responses obtained from the student survey, which will be used to improve the game mechanics in future iterations. The students' feedback and suggestions will be evaluated and incorporated into the next iteration of the game to enhance its effectiveness and learning engagement. Finally, the third part of this segment will be a control group study. The aim of this study is to examine whether there is a correlation in the actual academic performance improvement between students who played the virtual game and those who did not. Overall, this segment will provide a comprehensive evaluation of the virtual game and its potential to enhance student learning and engagement in ThermoFluid engineering.

Student survey

The survey questions consisting of 2 binary question and a 2 Likert scale questions (Table 2) were designed to collect information on several key aspects of the game's performance, including its ability to deliver the necessary information to complete the game, its effectiveness in teaching ThermoFluid concepts, and its ability to motivate and reinforce learning. The survey results showed that most students were able to find the information needed to complete the game, with 89.4% of respondents reporting success in this regard. Additionally, all students who completed the game were able to correctly answer 2 lower order “recall” type verification questions related to series and parallel pump installation, centrifugal pump operation, and backup pump installation. These findings suggest that the game was successful in delivering the necessary information to students. In terms of the game's effectiveness in teaching ThermoFluid concepts, most students felt that they were able to learn the concepts, with 70.5% indicating success in this regard. Among the 70.5% who replied yes, an overwhelming majority of students (87.2%) gave a score of 3 and above (out of 5) when they were asked if they felt that the game had effectively delivered the concepts to them. The survey also revealed that the students were more motivated to learn in the game-based environment, with an average score of 4.1 out of 5 for this question. The majority of students spent between 15-30 minutes completing the game. This duration is indicative of the game's ability to deliver the required information and concepts efficiently. It is noteworthy that while students indicated good master in the topic covered by the game, they did not spend an excessive amount of time on the game, hence, indicating that the game was concisely designed and effective in delivering the necessary material.

Table 2: Survey questions and results

No.	***Survey Question***	***Results***
1	Were you able to find the information required to play the game?	Yes (89.4%); No (10.6%)
2	Was this game useful in helping you understand the topic	Yes (70.5%); No (29.5%)

3	How well did the game teach the engineering concepts it covered? (Of those who answered yes to qns 2)	87.2% providing score of > 3 out of total score of 5
4	How well did the game motivate you to learn more about engineering	Average score: 4.1/5

Overall, the survey results suggest that the virtual game is a useful tool in teaching ThermoFluid engineering concepts to engineering students. The game successfully delivered the necessary information and concepts, and most students felt that they learned the ThermoFluid concepts effectively from the game. Importantly, the game-based environment was found to be more motivating for the students. The duration spent on the game suggests that it is a time-efficient way of delivering the necessary content. These findings indicate that the virtual game can supplement traditional classroom instruction in ThermoFluid engineering.

Student individual feedback response

The feedback provided by players on the game was extensive, covering various areas for improvement. Players highlighted the importance of clarity and instructions, recommending the addition of a dialogue history and clearer instructions on how to connect the pipes. They also expressed a desire for different modes of play, such as a story or career mode, and multiplayer gameplay to increase engagement and teamwork. In addition to the feedback on clarity and modes of play, players also recommended improving the game's settings. Specifically, players suggested improving the controls and mouse sensitivity to make the game more user-friendly and responsive. Additionally, players suggested adding more settings to the game to enhance the player experience. Some examples of the requested settings included options to customize the graphics quality, adjust the sound effects and music volume, and toggle different display options such as screen resolution and aspect ratio. Players also suggested the addition of more advanced settings for experienced players, such as the ability to fine-tune graphics settings and tweak gameplay mechanics. By offering a wider range of settings, players believe that the game could cater to a larger audience and provide a more personalized gaming experience. In terms of content, players wanted more scenarios from real-life industries and more learning points. They also suggested the addition of different chapters to the menu screen, a currency system, and making the game available as a mobile app to further increase engagement. While some players reported lag and performance issues, the technical aspects of the game were not given top priority, as educational value was the focus. However, players did suggest the optimization of graphics, frames, and game mechanics, and the addition of background music and a water-shooting mini-game related to the pump system to improve engagement and appeal. Lastly, players recommended making the pumps and pipes observable to enhance the educational value of the game, adding more colors and characters, improving the simulations, and giving the in-game robot a human face. Overall, the feedback provides valuable insights into areas for improvement and potential areas for further development and expansion of the game

Control group study to assess academic performance correlation

The study utilized a post-test control group design involving 432 students, who constituted the entire cohort enrolled in the Thermofluids module. With three weeks remaining before the final examination, all 432 students were notified about the availability of a game through Ngee Ann Polytechnic's learning management system (LMS) and were encouraged to participate in it. The game was positioned as a learning enhancement tool aimed at improving their comprehension of pump and pump system design. Two separate reminders were broadcasted via the LMS to prompt the student to complete the game. At the end of the three-week period, 200 students engaged with the game, while the remaining 232 students abstained, forming the control group for the study.

To assess the correlation between the virtual game and students' academic performance, the examination scores of both groups were compared using a normalized score derived from a specific examination question assessing pump and pump system design. The experimental group exhibited mean and median scores of 66.5 and 67, respectively, whereas the control group displayed mean and median scores of 61.3 and 63.5, respectively. These findings indicated a statistically significant improvement in the experimental group's performance, with mean and median assessment scores exhibiting an 8.48% and 5.51% increase, respectively, compared to the control group. Furthermore, the disparity in scores between the experimental and control groups was analyzed using a Gaussian distribution of the weighted probability of scores (Figure 6), illustrating a significant performance improvement for the experimental group. To test the statistical significance of the results, a hypothetical t-test was conducted with a significance level of 5%. The resulting probability was calculated as 0.0435, which falls below the selected significance level of 0.05. This outcome provides compelling evidence that the experimental group's performance was significantly superior to that of the control group.

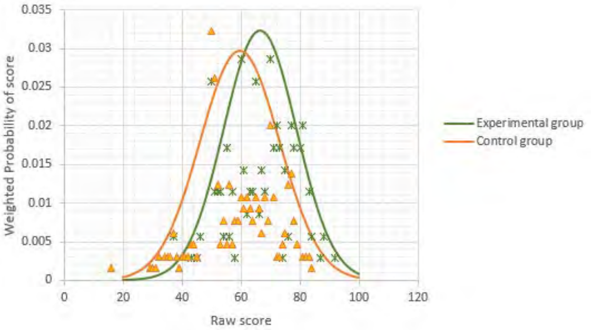

Figure 6: Gaussian distribution base on the weighted probability of scores

Conclusions

In conclusion, this study's findings support the potential of incorporating a virtual game into engineering education to enhance students' learning of ThermoFluid concepts. The virtual game demonstrated effectiveness as a supplementary learning tool, facilitating knowledge acquisition and contributing to improved academic performance. However, it is important to acknowledge that the virtual game utilized in this study was still in the prototype stage. Therefore, further investigations are warranted to explore the academic correlation of implementing a mature version of such a game within the curriculum. Furthermore, the study acknowledges a limitation inherent in the control group design, specifically concerning the students who abstained from participating in the virtual game. It is recognized that these students may have possessed lower academic abilities or lacked motivation, which could have influenced the study outcomes. To enhance the significance of future research in this area, it is recommended to conduct statistical profiling of students based on their past academic records before conducting group comparisons to ensure greater homogeneity in academic abilities. Additionally, conducting longer-term studies would yield more robust and stable results, allowing for a comprehensive assessment of the sustained impact of the virtual game.

Despite this limitation, the present study serves as a valuable reference point, highlighting the potential benefits of reinforced learning through the integration of an engineering virtual game. The outcomes indicate that incorporating a virtual game in engineering education can be an effective strategy for improving academic performance and enhancing students' understanding of ThermoFluid concepts. As such, this study provides support for the exploration and implementation of virtual games in engineering curricula, with the aim of fostering enhanced learning outcomes.

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ENTREPRENEURSHIP EDUCATION AT MAIZURU COLLEGE
-AIMING FOR REGIONAL REVITALIZATION IN THE NORTH KINKI REGION-

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Abstract

This paper describes the project to develop entrepreneurship human resource. It has goals as the below. a) Career development including after graduation (life plan, living expenses, insurance / pension system, etc.), b) Revitalization of Japan through regional revitalization (regional policy, local finance, regional economy, etc.), c) International expansion (related items such as the world economy and international law). The education system is designed to realize start-up achievements through solving regional issues. It has characteristics such as; a) Based on the established a regional platform (representative: Maizuru College), b) In collaboration with Maizuru City, two IT companies have been invited to establish a branch office and a satellite office, and they hope to accept students. c) Under the support of the Chutan Regional Promotion Bureau of Kyoto Prefecture, we established a corporate alliance called "Kyoto PMS" (Product Manufacturing Service). d) Participation in the startup research subcommittee of the Cabinet Office's regional revitalization SDGs public-private partnership platform. Concerning to the framework of school organization, in addition to setting up a startup human resource development center within the regional collaborative technology center, we build a system with industry-academia-public-finance platform in the north Kinki region as an advisory board. Also five equipment for this project are allocated to each facilities as the creative area that surrounds the centered creative studio. Specific contents have three steps. STEP 1: All technical college students learn about "entrepreneurship" for the future, STEP 2: Technical college students try to create things with free ideas (creative workshop, creative workshop area), STEP 3: Startup for technical college students. In the following themes, students will use the facilities and equipment they have applied for to create things. a) Manufacturing that connects virtual reality (VR) and reality, b) Solving regional issues using embedded/IoT technology, c) Promotion of AI and data science education using cutting-edge GPU environment and social implementation. d) Problem solving with an advanced robot arm development environment, e) Activities to improve the environment, including the living environment, through regional collaboration.

Keywords: *entrepreneurship education, regional revitalization, north Kinki region, IoT*

Introduction

Higher education in Western countries as a whole is trying to solve the current problems by back-casting. The movements to create teams across fields and to solve social issues are appearing in the activities of companies and the founding of NPOs and NGOs. There is a method of procuring the necessary resources after clarifying the goals.

The Japanese government is promoting education about entrepreneurship from an economic perspective and the realization of a sustainable society.

A startup project has started at National Institute of Technology with the support of the Ministry of Education, Culture, Sports, Science and Technology, MEXT. Here we describe the discussion on startup and entrepreneurship, and the plan of Maizuru National College of Technology.

Entrepreneurship and Startup

In considering the possibility of entrepreneurship for the student in future, it is important to touch on the perspectives of entrepreneurship, startup, project management, and business administration as well as the knowledge necessary for entrepreneurship.

Entrepreneurship has a broad meaning and is used to include startup, creation of business plan, ventures, etc. According to Irie, A. (2019), entrepreneurship consists of four areas, that is;

1) International Entrepreneurship: multi national company, e.g. Uber, airbnb
2) Social Entrepreneurship: established with priority given to social and public purposes, e.g. development type of conventional NPO
3) Institutional Entrepreneurship: transcending social norms, establishing new norms, and changing the government system, e.g. NPO Florence's approved small-scale nursery school business
4) Intrapreneurship: entrepreneurship in a large company, e.g. Soup Stock Tokyo from Mitsubishi Corporation

Startup elements include founder, business opportunity, founder and team, and finance. There is a debate as to whether to start the business first and prepare the environment, or to launch the business when the opportunity is ripe.

According to Phillips, J. (2004), project management is the process of leading the work of a team to achieve all project goals within the given constraints. This information is usually described in project documentation, created at the beginning of the development process. The primary constraints are scope, time, and budget. The secondary challenge is to optimize the allocation of necessary inputs and apply them to meet pre-defined objectives.

Entrepreneurship from the perspective of business administration requires both a macroscopic perspective that deals with the entire organization and relationships between organizations, and a microscopic perspective that deals with behaviour within the organization. Figure 1 describes the framework that is translated from Irie, A. (2019).

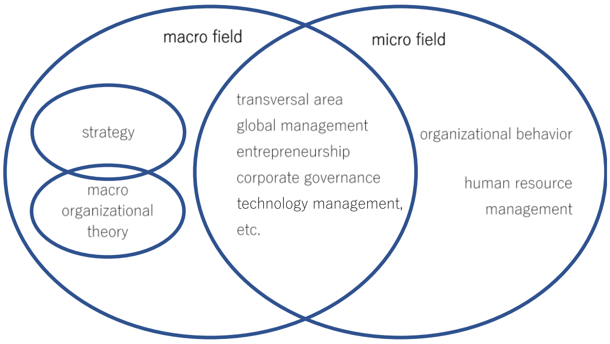

Figure 1 Entrepreneurship from the perspective of business administration

Implementation at Maizuru College

This project has the following goals.
a) Career development including after graduation: life plan, living expenses, insurance / pension system, etc.
b) Revitalization of Japan through regional revitalization: regional policy, local finance, regional economy, etc.
c) International expansion: related items such as the world economy and international law, etc.

The education system is designed to realize start-up achievements through solving regional issues.

It has characteristics such as;
a) Based on the established a regional platform (representative: Maizuru College),
b) In collaboration with Maizuru City, two IT companies have been invited to establish a branch office and a satellite office, and they hope to accept students.
c) Under the support of the Chutan Regional Promotion Bureau of Kyoto Prefecture, we established a corporate alliance called "North Kyoto PMS" (Product Manufacturing Service).
d) Participation in the startup research subcommittee of the Cabinet Office's regional revitalization SDGs public-private partnership platform.

In the campus, the equipment for this project are allocated to each facilities as the creative area that surrounds the centered creative studio. In the respective themes, students will use the facilities and equipment they have applied for to create things.

Concerning to the framework of school organization, in addition to setting up a startup human resource development center within the regional collaborative technology center, we build a system with industry-academia-public-finance platform in the north Kinki region as an advisory board.

Three steps common to each technical college

STEP1: All KOSEN students learn about "entrepreneurship" for the future.

Focusing on classroom lectures, they learn the concept and basic knowledge of startup mentioned above.

STEP2: KOSEN students try to create things with free ideas (creative workshop, creative workshop area).

STEP3: Startup trial for KOSEN students

The way to establish the company to start is shown to motivated students. In addition to current internships, participants will participate in business launches within local companies.

Three steps are undergoing in Maizuru college as following corresponding steps.

STEP1: Contents to be learned as basic knowledge

Two materials are considered to prepare the contents as below;

a) SME management consultant

Many of the local companies around us are small and medium-sized, SME, enterprises, and the knowledge necessary for SME enterprise diagnosticians who evaluate their activities and give advice is useful for startup and for career formation for working at companies. Therefore it is considered to have affinity with this project.

The brief list of contents including related area is described in Table1.

b) Learning in high school synthetic inquiry time.

Yoshida, M. (2022) has focused on the "gap" between the knowledge necessary for high school teachers to teach group work for solving local problems and the knowledge they have already acquired. It will be useful for learning up to the third year of technical college. The summarised contents are shown in Table 2. Each row indicates acquired knowledge as a teacher in high school, gap between required knowledge in terms of university and adult education, and the knowledge required for instruction respectively, from left to right.

Through the discussion among the staff at Maizuru college, in fiscal year 2023, it will be held during special activities mainly for third-year students, so the number of hours for the implementation is limited. We considered the following policy.

a) Overall view of manufacturing and its social implementation are related to various fields, e.g. ergonomics, project management, etc.

b) Knowledge of entrepreneurship and management perspective is necessary for manufacturing

c) Knowing that there are process management, cost management, etc., students will have a vision and perspective to see the overall picture of manufacturing

With the cooperation of Honda Motor Co., Ltd. as an example of manufacturing, we will explain "from car design to manufacturing" and connect it to a wide range of related fields.

STEP2: Technical college students try to create things with free ideas

STEP2 is carried out with creative workshop, etc. and it is mainly in creative workshop area. In addition to being conducted in classes and practical training, it also includes practical content such as internships that destination are aware of startup project of KOSEN. The

Table 1 Brief view of the issues of SME management consultant

Item	Content
Economics/Economic Policy	National accounts and key economic indicators Financial goods market analysis and IS curve, Money market analysis and LM curve
Financial accounting	Financial statements, Management analysis
Business management theory	Management strategy, Organizational theory, Marketing, Business plan planning/preparation/analysis
Operational management	Production management, Store/sales management, Project management, Labor, Insurance
Management legal affairs	Civil law, corporate law, etc., Intellectual property rights, etc., Tax
Management information system	Basic knowledge of information technology, Cloud computing
SME Management/SME Policy	Management, Policy

Table 2 Contents of learning in high school integrated inquiry period

Acquired knowledge as a teacher in high school	The “gap” between the knowledge required for teaching and the knowledge high school teachers already acquired		
Knowledge High School Teachers Already Acquire	Contents at university	Contents of adult education	Knowledge required for instruction
N/A	N/A	Municipal business	1. What kind of issues are there in the region?
Undergraduate specialized subjects	Business Administration	In-house training/ self-improvement	
Undergraduate specialized subjects	urban engineering	(Recruitment of experts)	
Undergraduate specialized subjects	history, etc.	(Recruitment of experts)	
Guidance for students such as liberal arts subjects*1 Special Activity Theory*2	N/A	coaching theory	2. How to lead group work outside one’s area of expertise
	communication theory	On-boarding training, etc.	
	leadership theory	Management training, etc.	
	Others (human resource management theory, critical path theory, etc.)	Management methods, process charts, and critical path theory to increase organizational efficiency	
Graduation thesis guidance on how to write papers and reports	no gap (Professing reports, graduation thesis, etc. at the university)	no gap (on-the-job training for in-house document creation, etc.)	
Social awareness education theory such as teacher training courses, modern society and social education, social education management theory (*2)	Business Administration career design theory corporate research	on-the-job training	3. Career Formation theory necessary for advising students to design their own life
Career Education Theory (*2)	career design theory	Personnel evaluation, etc.	

*1:Elementary and Secondary Education Bureau Student Affairs Division (2010) "Student Guidance Guidelines" Ministry of Education, Culture, Sports, Science and Technology

*2: Examples of subjects and syllabuses of the College of Human Studies, University of Tsukuba (2021)

five themes to be implemented are as follows covering most departments of Maizuru college.
a) Manufacturing that connects virtual reality (VR) and reality,
b) Solving regional issues using embedded/IoT technology,
c) Promotion of AI and data science education using cutting-edge GPU environment and social implementation.
d) Problem solving with an advanced robot arm development environment,
e) Activities to improve the environment, including the living environment, through regional collaboration.

STEP3: Startup trial for technical college students

Maizuru City, Maizuru National College of Technology (including students), and KDDI have developed a small-scale river water level monitoring system. It has been socially implemented as Maizuru City comprehensive monitoring information distribution system, Maizuru city (2023).

In the process of social implementation, a startup procedure has been derived by PMI Japan chapter and Maizuru college. It is a methodology that combines regional problem solving and SDGs, Takahashi M., Toshihiro K., Utsumi Y., (2022).

The procedure is as followings.

a) early plan
  Creating an initial lean canvas and it is commonly used.
b) Initial goal mapping
  Initial target setting
  Create an initial logic model
c) Exchange of opinions with external experts, etc.
  Lean canvas and logic model modifications
d) On-site trial
  Consideration with early adopters
  Create a benefit list

It is based on actual activity including the students in Maizuru city, and it can be a motivation for current students.

Conclusions

A project at Maizuru college to cultivate the human resouerce in terms of stratup and entreprenorship is introduced.

Considering the required three steps, the current status of coresponding education in high school and companies, and limited period undergoing education, the followings is being carried out in 2023.

a) The relation between entrepreneurship and startup

The lectures by 2023 July indicate most of students are not familiar with entrepreneurship and startup, but the view point of the realization of their dream in future by startup seems helpful to understand.

b) STEP1: Contents to be learned as basic knowledge

First thing is to broaden student's horizon. The starup has no established formula for success, that is the subsequence of selection of possible solutions in changind surroundings. Students sometimes hesitate to choose one decision at own risk where conventional education in engineering and science often provides one best solution for one problem.

c) STEP2: Technical college students try to create things with free ideas

Miazuru college provides five themes that students can evolve their own ideas. Students have opportunities to undestand each theme relates to various fields and also it has been establised by activities of predecessors in society.

d) STEP3: Startup trial for technical college students

As introduction of a startup methodology, examples by successful businessman are introduced with discussion at present.

Acknowledgements

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Developing an AI-powered Presentation Tool for Engineering Education Using Augmented Reality (AR) Technology

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Abstract

The COVID-19 pandemic has resulted in a growing demand for innovative online educational tools, particularly in the field of engineering. In response, a team of students from the Hong Kong Institute of Vocational Education (Sha Tin) has developed Present AR, an AI-powered presentation tool that enhances the virtual presentation experience for engineering education. The project has successfully transitioned into a start-up that has been funded by Hong Kong Science and Technology Park, and is currently collaborating with IVE to further develop the product.

Present AR is a presentation tool that leverages augmented reality (AR) technology and AI algorithms to create a highly interactive and engaging learning experience. The tool enables presenters to virtually interact with engineering models and diagrams, providing a more immersive and dynamic learning experience that can enhance understanding and retention of complex engineering concepts. One of the key features of Present AR is its AI-powered gesture recognition, which tracks the presenter's movements and integrates them seamlessly into the virtual environment, creating a more personalized and immersive learning experience.

The potential of Present AR to revolutionize engineering education lies in its ability to provide a more dynamic and interactive learning experience. For instance, a presenter could use Present AR to demonstrate the operation of a complex machine or process by virtually manipulating 3D models and providing detailed explanations, facilitating a more effective understanding of the machine or process than through traditional methods.

Furthermore, Present AR's interactive capabilities can also foster collaboration between students and instructors in virtual classrooms, allowing them to work together on projects and simulations in real-time. This approach can help students develop teamwork skills while providing a more engaging and effective learning experience.

The development of an AI-powered presentation tool like Present AR holds significant potential for engineering education in the post-pandemic era. By leveraging AR technology and AI algorithms, Present AR can offer a more dynamic and immersive learning experience, which can enhance understanding and retention of complex engineering concepts. Additionally, its interactive capabilities can facilitate collaboration and teamwork, providing a more engaging and effective learning experience for students. The tool's use of AI-powered gesture recognition allows for a more personalized and immersive learning experience, with the potential to improve the effectiveness of online engineering education. Further research could explore the potential applications of Present AR for other educational fields and settings.

Keywords: *Present AR, virtual presentation, engineering education, interactive learning, immersive experience, gesture recognition, post-pandemic era*

Introduction

The COVID-19 pandemic has caused worldwide impact on education. Educational institutes are forced to shift from traditional face-to-face learning to remote and online learning environments (Aristovnik et al., 2020). This rapid transition has highlighted the need for innovative educational methods that can keep students engaged, motivated, and connected in these challenging times (Johnson et al., 2020). Though Passey (2021 et. al) addressed that these challenges about integrating technology in education are vital for ensuring successful implementation and positive student outcomes, there is also an opportunity to bring in other innovations to tackle the challenges.

In response to this need, our team observed that conventional online lectures, delivered through platforms such as Zoom or Microsoft Teams, often relied on static lecture notes and lacked the interactivity and engagement required to maintain students' attention and interest. This observation led us to explore the potential of Augmented Reality (AR) technology as a means to transform the online learning experience.

We proposed a novel system, Present AR, an AI-powered presentation tool for education that leverages AR technology to immerse learners into the lecture content and enable them to interact with virtual objects in the presentation. Present AR aims to provide a more engaging, interactive, and immersive learning experience compared to traditional online lectures.

The proposed system has garnered significant recognition for its innovative approach to enhancing engineering education. Present AR has been awarded in various competitions and has received positive feedback from educators, students, and industry experts.

Encouraged by this success, our team decided to commercialize the product and founded a start-up with a mission to revolutionize the way we learn by harnessing the power of AR and AI technologies. This paper presents a story of the development of Present AR, detailing its features, methodology, and the impact it has had on the educational landscape.

Literature Review

This literature review aims to provide insights into the development and applications of AR in education, particularly focusing on engineering education. Several studies have demonstrated the benefits of using AR as a learning tool, and this review will discuss those findings in detail.

AR in Education

Over the past few years, AR has emerged as a promising technology for educational purposes. AR is an interactive experience that overlays digital information and virtual objects onto the user's view of the real world (Azuma, 1997). In the context of education, AR has been found to be effective in increasing student engagement, motivation, and enhancing learning outcomes (Radu, 2014).

Figure 1 presents one of the early applications of AR in education namely AR-Dehaes model (Billinghurst & Duenser, 2012), which focused on supporting collaborative learning in the classroom by providing hands-on experiences to students. The authors concluded that AR could significantly improve students' understanding of complex concepts, retention of information, and collaboration skills.

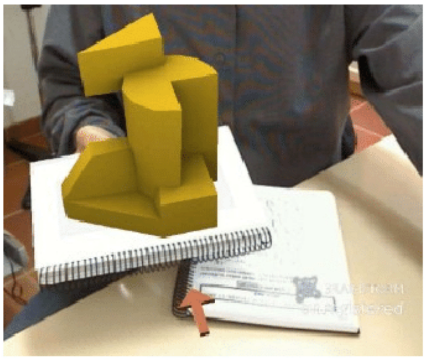

Figure 1. Screen capture of AR-Dehaes (Billinghurst & Duenser, 2012)

A meta-analysis by Santos et al. (2014) investigated the impact of AR on learning outcomes and found that AR-based interventions led to significant improvements in students' cognitive and affective outcomes. The study highlighted that AR could be particularly useful for teaching abstract concepts, as it allows students to visualize and manipulate virtual objects in real-time.

AR in Engineering Education

In recent years, AR has been increasingly applied to engineering education, where it has been shown to enhance students' understanding of complex concepts and improve their problem-solving abilities (Mora et al., 2017). For instance, AR has been used to teach civil engineering students about structural analysis and design (Wojciechowski & Cellary, 2013), allowing them to visualize forces and deformations in real-time.

Another study by Pogodaev et al. (2022) explored the use of AR in teaching electrical engineering concepts. Their findings indicated that AR-based learning environments significantly improved students' understanding of complex concepts, such as electromagnetic fields, compared to traditional teaching methods.

AR has also been found to be effective in enhancing students' spatial visualization skills, which are critical for engineering students (Bacca et al., 2014). In a study by Kaufmann and Schmalstieg (2003), the authors developed an AR system to teach geometry and found that students' spatial visualization skills improved significantly after using the system.

Moreover, AR has been used to support collaborative learning in engineering education. A study by Dünser et al. (2012) investigated the use of AR in a collaborative design project and found that AR significantly improved students' communication and collaboration skills.

AR Innovation in Video-Conferencing

In recent years, augmented reality (AR) innovation has also made significant strides in the realm of video-conferencing. Two notable studies have explored the potential of AR in enhancing video communication and live presentations. Saquib et al. (2018) conducted a study titled "Interactive Body-Driven Graphics for Augmented Video Performance," which revealed the technical capability to generate immersive real-time video processing for immersive and interactive graphics using human body tracking technology. (*Figure 2*) This development enables more engaging and dynamic video-conferencing experiences, transforming the way people communicate and collaborate remotely.

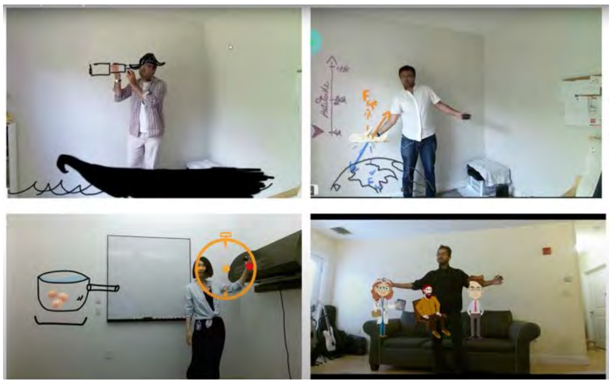

Figure 2. Outcome of Saquib et al. (2018) Study

Another ground-breaking solution was RealityTalk presented by Adobe and the University of Calgary in a study by Liao et al. (2022), which focused on building real-time speech-driven AR presentations for AR Live storytelling. This research showcases the potential of AR in creating more captivating and interactive live presentations, elevating the art of storytelling through the seamless integration of AR elements with real-time speech. These advancements in AR innovation for video-conferencing and live presentations not only enhance communication experiences but also open new possibilities for collaboration and interaction in various fields, including education, business, and entertainment.

Feature of Present AR

The literature reveals that AR has the potential to revolutionize engineering education by providing students with interactive and immersive learning experiences. AR has been found to enhance students' understanding of complex concepts, improve their problem-solving abilities, and strengthen their spatial visualization and collaborative skills. As such, the development of an AI-powered presentation tool for engineering education using AR technology seems to be a promising endeavor.

Therefore, the team decided employing the augmented reality technology, with the help of human-motion tracking AI technology to develop an education tool for creating lively presentation. Present AR is an innovative AI-powered presentation tool designed to enhance engineering education using AR technology. This section outlines the key features of Present AR, along with relevant references that support the effectiveness of these features in the context of e-learning.

Built for iPad: Present AR is specifically designed for the iPad, as iPads are widely adopted as a primary device for e-learning. The large touch-screen display of the iPad allows for a more immersive and interactive experience, making it an ideal platform for AR-based educational tools (Hwang & Tsai, 2011).

AR Integration: Present AR seamlessly integrates AR technology to overlay virtual objects and information onto the user's view of the real world (Dunleavy, 2014). This integration enables students to visualize and manipulate complex engineering concepts in real-time, enhancing their understanding and retention of the material (Martín-Gutiérrez et al., 2017).

Interactive Presentation with Natural Input: Presented in *figure 3, t*he application supports various natural input methods, such as human-motion tracking, voice control, and gesture control (Billinghurst et al., 2015). These features allow users to interact with the virtual objects in a more intuitive and engaging manner, fostering a more effective learning experience (Wu et al., 2013).

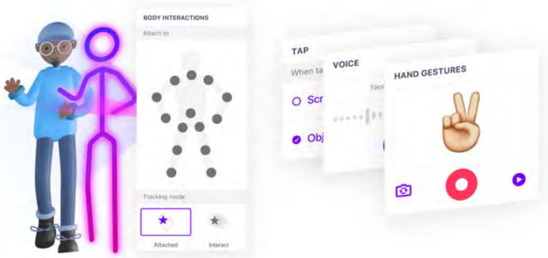

Figure 3. Natural input supported by Present AR

Immersive Experience: Present AR provides an immersive experience by enabling users to directly interact, as shown in *Figure 4*, with virtual objects (Radu, 2014). This interactivity promotes a deeper understanding of complex engineering concepts, as students can actively explore and manipulate virtual representations in a 3D space (Santos et al., 2014).

Figure 4. Direct interaction between speaker and virtual subject in Present AR

No Coding Programming Interface: The application features a user-friendly, no coding programming interface, allowing educators to easily create and customize interactive AR-based presentations without the need for extensive programming knowledge

(Bacca et al., 2014). With the drag-and-drop no-coding user interface in *Figure 5*, this feature ensures that a wide range of educators can effectively utilize Present AR in their teaching practices.

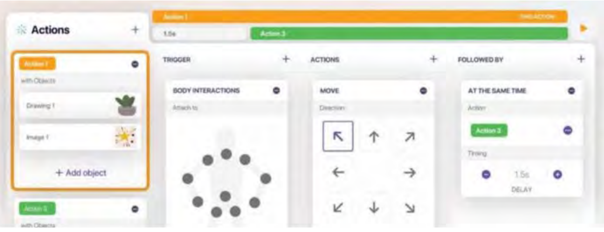

Figure 5. No-coding programming interface of Present AR

Compatibility with Videoconferencing Tools: Present AR is compatible with popular videoconferencing tools facilitating online learning and remote collaboration(Crompton & Burke, 2018). *Figure 6* demonstrates Present AR working with Microsoft Team in a pitching activity. This feature enables educators and students to engage in interactive and immersive AR-based learning experiences, even when they are physically separated.

Figure 6. Present AR team showcasing Present AR with video conferencing Tool.

Development Methodology

The study employed the Scrum framework for the design and development of the mobile application, with a focus on incorporating feedback from educators and students, as well as gaining insights from competitions.

Scrum Framework for Mobile Application Development

Scrum is an agile project management framework that emphasizes iterative and incremental development, collaboration, and adaptability (Schwaber & Sutherland, 2017). The Scrum framework was chosen for this project due to its ability to facilitate rapid prototyping and continuous improvement, which is essential when developing innovative educational tools (AltexSoft, 2019).

Presented in *figure 7*, the Scrum process was divided into several sprints, each lasting two weeks. The sprints included planning, designing, development, testing, and review stages. Throughout the process, the Scrum team held daily stand-up meetings to discuss progress and address any challenges. This iterative approach allowed the team to continuously refine the mobile application and incorporate feedback from stakeholders.

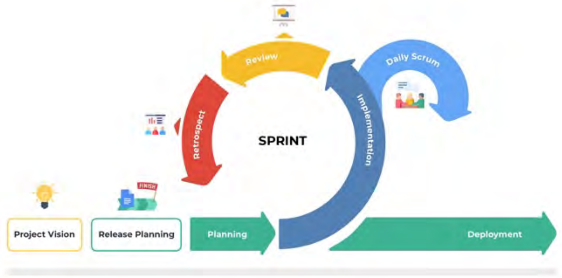

Figure 7. Development Life Cycle of Scrum Methodology (Amoniac, n.d.)

Stakeholder Feedback and Retrospective

To ensure the AR-based presentation tool met the needs of engineering educators and students, feedback was collected throughout the development process. The primary source of feedback was from software engineering teachers and students at the Department of IT, Hong Kong Institute of Vocational Education (Sha Tin). They were involved in providing feedback during the sprint reviews and were given opportunities to test and evaluate the mobile application.

Alongside this, the team participated in various competitions, presenting the mobile application to mentors and judges, who provided valuable feedback on the effectiveness and usability of the AR-based presentation tool. The insights gained from these competitions helped the team identify areas for improvement and refine the application further.

In both cases, the feedback was incorporated during the sprint retrospective, where the team analysed the comments and suggestions, prioritized them, and integrated them into the following sprint planning(Derby & Larsen, 2006). This continuous feedback loop allowed the team to develop a more effective and user-friendly AR-based presentation tool for engineering education.

This methodology enables the development to gather early feedback with the minimum viable product (figure 8.1) and figure 8.2 presents the improvement of present AR of the App Store version of Present AR.

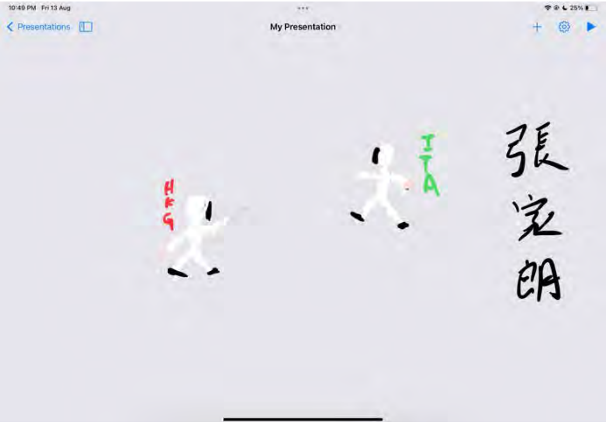

Figure 8.1. Minimum viable product of Present AR

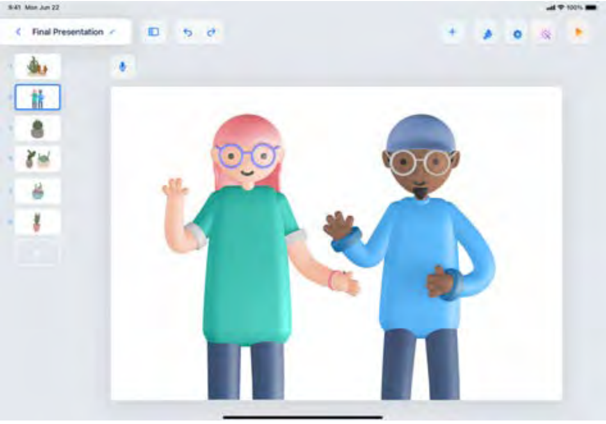

Figure 8.2. App Store version of Present AR

The Scrum framework was instrumental in the development of the AI-powered AR presentation tool. The iterative and incremental nature of Scrum allowed the team to quickly adapt to stakeholder feedback and refine the mobile application. By collecting and incorporating feedback from educators, students, and competition mentors and judges, the team ensured that the final product effectively addressed the needs and requirements of the target users.

Findings at Pilot Study

To evaluate the effectiveness and usability of Present AR, the company conducted a 3-weeks pilot study involving 50 teachers in the STEM (Science, Technology, Engineering, and Mathematics) area. These educators were invited to use Present AR for their presentations, and their feedback was collected through surveys to gauge their experience with the system. The results of the pilot study are presented in *Figure 9.*

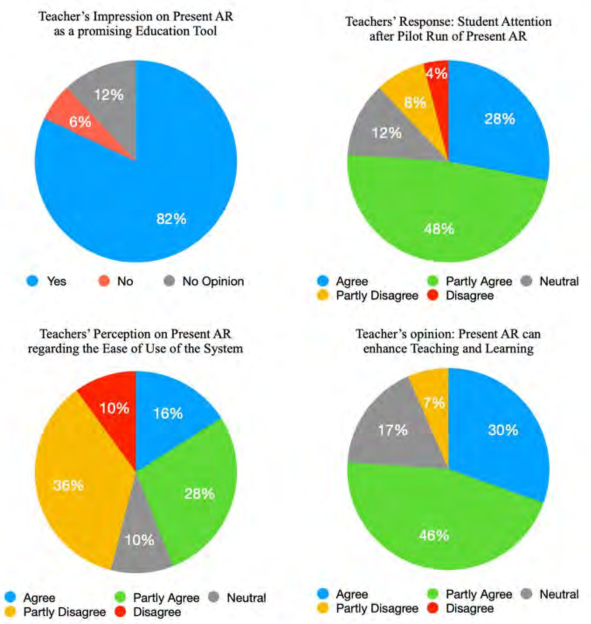

Figure 9. Survey Results of Present AR Pilot Run

Interest in Present AR: A significant majority of the teachers (82%) found Present AR to be interesting, indicating that the system has captured the attention of educators and is perceived as a promising educational tool.

Student Attention: 76% of the teachers observed that presentations using Present AR initially attracted the attention of their students, suggesting that the AR-enhanced presentations have the potential to engage learners more effectively than traditional presentations.

Ease of Use: However, 46% of the teachers reported that they found the tool difficult to use. This highlights the need for improved user interfaces and additional training resources to facilitate the adoption of Present AR among educators.

Teaching and Learning Enhancement: Finally, a strong majority of the teachers (76%) believed that the use of Present AR could enhance their teaching and learning experience. This positive feedback underscores the potential impact of Present AR on education and demonstrates the value of integrating AR technology into classroom settings.

The results of the pilot study provide valuable insights into the strengths and areas for improvement of Present AR. By addressing the concerns raised by the teachers and capitalizing on the positive aspects of the system, the development team can continue refining Present AR to better cater to the needs of educators and learners, ultimately achieving the goal of revolutionizing the educational landscape.

Achievements

Present AR has garnered numerous accolades for its innovation and potential in the educational sector, including a Second-Class Award at the Mobile App Innovation Contest of the Greater China Region, a Gold Awardat the China Greater Bay Area 5G Application Innovation Contest, and the championship title at the Innovate for Future competition. Other achievements include a 1st Runner-up position at the Young Professional Exhibition and Competition, the Hong Kong Techathon 2023 championship, and a Gold Award at the Internet+ China Student Entrepreneurship Competition. The Hong Kong Science and Technology Parks Corporation (HKSTP) has provided seed funding from the Ideation Programming, enabling the transition from an educational project to a commercial venture and the establishment of 417Techn Limited, the company behind Present AR.

Collaborations with educational institutions have further strengthened Present AR's market position. These partnerships enable the team to understand the unique requirements of different educational environments and tailor the system accordingly, ensuring wide applicability and relevance.

Present AR is currently available on the Apple App Store, making it accessible to millions of users worldwide. This milestone showcases the team's dedication to bringing their innovative solution to the masses and signifies the potential impact Present AR can have on the future of education.

The numerous awards and recognitions, along with the successful commercialization of Present AR, serve as a testament to the system's potential to revolutionize the educational landscape. The team behind Present AR has demonstrated that, by adopting innovative technologies and methodologies, barriers can be overcome, and new horizons in education can be explored for the betterment of learners globally.

Limitation

Despite its numerous achievements and positive impacts on education, Present AR is not without its limitations. As with any technology, there are areas in which the system can be improved to better cater to the needs of its users. The following are some of the current limitations of Present AR:

Lack of support for multiple presenters: Present AR currently does not support multiple presenters within the same AR presentation, which might limit its applicability in certain educational scenarios where team presentations or panel discussions are common. Addressing this limitation by allowing multiple users to interact and present simultaneously could further enhance the collaborative and interactive nature of the learning experience.

Hardware limitations: Present AR is designed to work with the built-in camera of iPads, which could restrict its accessibility to users who do not own this specific device. Expanding its compatibility with a wider range of devices, including smartphones and other tablets, could increase its potential user base and make the technology more inclusive. And the app's performance is largely determined by the processing power of the iPad model it runs on. At present, the app runs best on iPad Pro M2, which may not be the most cost-effective option for some users. Optimizing the app for lower-end devices could make it more accessible and ensure a smooth user experience across various iPad models.

Platform dependency: Present AR is currently available only for iOS, as the development team has employed some platform-dependent frameworks such as the Vision framework and Apple Pencil framework. This limits the app's reach, as it excludes users of other operating systems like Android. Developing a cross-platform solution or employing platform-independent frameworks could help extend the app's availability to a broader user base.

While these limitations may present challenges, they also offer opportunities for further development and improvement of Present AR. By addressing these issues and continuously refining the system, the team can ensure that Present AR remains at the forefront of educational innovation and continues to provide engaging, interactive, and immersive learning experiences for students.

Future Developments

The future exploration of Present AR extends beyond its application in engineering education. One promising direction is to explore its potential in other disciplines such as biology, chemistry, and architecture. By integrating subject-specific content and models, Present AR can provide students with interactive and immersive learning experiences in these fields. This opens up opportunities to enhance understanding and engagement, allowing students to explore complex concepts in a hands-on and visually stimulating manner.

Furthermore, Present AR has the potential to serve as a captivating storytelling tool for primary and secondary school students. By combining augmented reality with narrative elements, Present AR can bring stories to life, creating an interactive and immersive storytelling experience. Students can engage with virtual characters, environments, and objects, fostering imagination, creativity, and language skills. This application of Present AR has the potential to revolutionize traditional storytelling methods and make learning more enjoyable and impactful for young learners. The team conducted exploratory discussion with schools' management. And a principal of primary presented Present AR at the Senco-Masslink iPad BYOD Leadership Conference 2023 *(Figure 10)*. Present AR initially received positive feedback and the team is planning for further action in this sector.

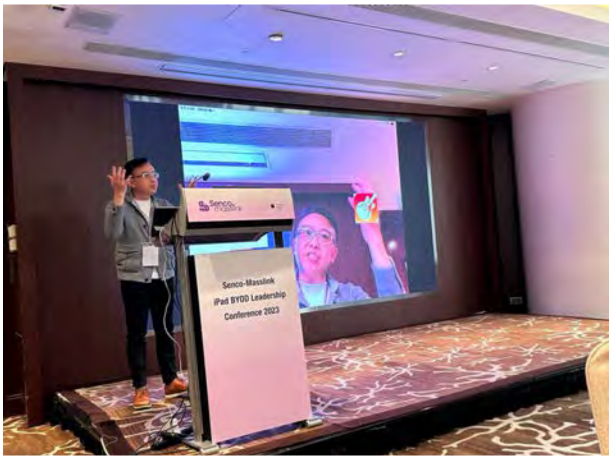

Figure 10. Primary School Principal demonstrated Present AR at Senco-Masslink iPad BYOD Leadership Conference 2023

In addition to its educational applications, Present AR holds promise in the commercial realm. One area where Present AR can be utilized is in roadshows and product presentations. By leveraging its augmented reality capabilities, Present AR enables companies to showcase their products in a more interactive and engaging manner. Virtual product models and visualizations can be shared, allowing potential customers to interact with and explore products in real-time, enhancing their understanding and connection with the offerings.

Moreover, Present AR can transform the landscape of meetings and presentations in the corporate world. By providing a dynamic and immersive platform, Present AR can enhance engagement and productivity in business meetings. Virtual participants can collaborate, share visual content, and interact with 3D models, making meetings more interactive and impactful. This opens up possibilities for enhanced communication, idea generation, and decision-making processes.

Conclusions

In conclusion, this paper has presented the development story of Present AR, an AI-powered presentation tool for education that utilizes Augmented Reality (AR) technology to enhance the learning experience. The COVID-19 pandemic has underscored the importance of innovative and engaging educational methods, as traditional face-to-face learning shifted to remote and online environments. Present AR was developed in response to the observed limitations of conventional online lectures and aimed to provide a more interactive and immersive learning experience.

The Scrum framework was adopted to develop Present AR, enabling rapid prototyping and continuous improvement. Throughout the development process, the team actively sought feedback from educators, students, and industry experts, incorporating their insights into the design and functionality of the system. This iterative approach, combined with the innovative features of Present AR, has resulted in a tool that effectively addresses the challenges faced by educators and students in the current educational landscape.

Present AR has received significant recognition for its innovative approach to enhancing engineering education, with positive feedback from various stakeholders and awards in competitions. The success of the system has led to the commercialization of the product and the founding of a start-up company, further emphasizing the potential impact of Present AR on the future of education.

Moving forward, the team will continue to refine Present AR and explore additional applications of AR and AI technologies in education. The ultimate goal is to revolutionize the way we learn and create more engaging, personalized, and effective learning experiences for students around the world. By combining cutting-edge technologies with a deep understanding of educational needs, Present AR serves as a promising example of how innovation can transform the way we teach and learn in the 21st century.

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SELF-PHY: AN EXAMPLE OF COLLABORATION BETWEEN INSTITUTE, INDUSTRY AND NON-GOVERNMENT & NON-PROFIT ORGANIZATION IN DEVELOPING HEALTHCARE SYSTEM

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Abstract

Self-Phy is a physiotherapy exercises learning platform developed by Vocational Training Council's students under the Project Based Learning framework with the support from industry and Non-Government & Non-Profit Organization (NGO&NPO) during coronavirus period. The collaboration between academic, industry, NGO&NPO plays an important role in nurturing young talents as it offers a valuable opportunity for students to learn and adopt the state-of-art technologies from the industry and understand the needs of society by the events organized by NGO&NPO to better refine their solutions to the problems. The purpose of this study is to present the project details of Self-Phy, collaboration framework of Self-Phy between institute, industry and NGO&NPO during the coronavirus period, and to propose a post corona virus era collaboration framework in order to enhance the quality of engineering education as well as suggesting future research directions.

Keywords: *Artificial intelligence education, industry institution collaboration, physiotherapy, healthcare system, project-based learning*

Introduction

Project-based learning (PBL) is one of the popular teaching and learning method to promote self-directed, self-regulated and self-reflecting learning in order to cultivate students' positive values and attitudes to overcome with the challenges of the 21st Century. Vocational Training Council (VTC) in Hong Kong has adopted Project based learning in recent years to encourage students to design, develop and implement solutions to solve real-world problems.

Self-Phy is a physiotherapy exercises learning platform developed by VTC's students under the PBL framework with the support from industry and Non-Government & Non-Profit Organization (NGO&NPO) during coronavirus period.

The project team identified that Hong Kong has a high demand of physical therapist, the ratio between registered physiotherapist and patient is 1:3800. Of the 3800 patients, each physiotherapist treats an average of 662 elderly people. The average queening time of physical therapist service in public hospital is about 33 weeks. If the patients can pay for the high medical fee, they can change to private hospital to purchase physical therapist services. However, the medical fee of physical therapist services is a bit expensive to elderly if they decided to visit private hospital instead of public hospital. There is a trade-off between the queening time and money in selecting physical therapist services in public or private hospital.

Pointing to the situation of Hong Kong, the project team designed and developed a healthcare system "Self-Phy" to solve the problem of long queening time for physical therapist services in public hospital. Self-Phy uses artificial intelligence technologies to distinguish whether the patient's movements are standard, records and reminds the patient whether s/he has completed the daily physiotherapy exercises. This software can provide guidance for patients who have turned to home physiotherapy training because of the pandemic, avoiding the impact of wrong postures on the treatment effect, and making physiotherapy no longer limited by time and place.

Figure 1: Demonstration of Self-Phy

Literature Review

With the competition on the development of new technologies are increasing tremendously in recent decades, which forces all industrial sectors are more likely to recruit high skilled and qualified graduates as they can bring more value to the company and help the company to survival in today's highly competitive environment (Ramakrishnan & Yasin, 2011). On the other side, technical institute, and students both notified that the importance of developing students' skills and technological options as early as possible in order to fulfil the needs in the job market. Institute and industry collaboration in developing projects is one of the best ways to train students and transform students to be a work ready talent.

The concepts of institute and industry collaboration was first introduced by Sunderland Technical College in Northern England in 1903, which was known as the "Sandwich Program" (Zhao & Wang, 2008). The collaboration between Institute and industry has existed for more than ten decades, especially in the area of technology. However, there is still a missing research gap focusing on developing healthcare system by the collaboration between institute and industry in the context of Hong Kong especially with the participation of NGO&NPO (Samuel & Omar, 2015).

Thus, the objective of this study is to investigate and fill the research gap of the collaboration framework between three parties for the coronavirus period and post corona virus era for the artificial intelligence-based healthcare system.

Collaboration Framework

The Self-Phy project started from September 2021 as a final year project of Higher Diploma in Software Engineering (SE) students. The Self-Phy project team consists of 4 SE students, industrial partner, and NGO&NPO. The role of students in this project is to design and develop a prototype according to the input from industrial partner and NGO&NPO. The role of industrial partner in this project is to provide technical support and training to students that enhance students' technical skills, while the role of NGO&NPO in this project is to line up students with potential users by organizing different learning activities which allows students to design user-centred and user-friendly project prototype.

Basically, the collaboration framework is similar to the traditional Software Development Life Cycle (SDLC), which consist of four phrases: (1) Planning, (2) Analysis, (3) Design and (4) Implementation. The first task is to select an appropriate software development methodology. There are serval software development methodologies could be chosen for a project such as system prototyping, iterative development, Parallel development etc. Since the number of development team members of Self-Phy project were small and the project scope and size were relatively small when comparing to the actual project in the market. Therefore, the project team decided to adopt agile development model throughout the SDLC as we think the efficiency and effective of communication with industrial partner and NGO&NPO is the most important part in developing a hight quality project prototype.

Agile model is a popular Software Development Methodology used to manage software development projects among start-up community as it provides high flexibly and extendibility during the system development life cycle. The visualization of the agile model as shown in figure 2 below. The project was conducting through collaborative development and ongoing improvements through iteration. In the agile development model, each iteration is considered a short-term "frame", typically lasting one to four weeks. Dividing the overall project into smaller parts helps minimize project risk and reduce overall project delivery time requirements (Tore & Torgeir, 2008). Each iteration involves a team going through the full software development lifecycle, including planning, requirements analysis, design, coding, and testing, before presenting a working product to customers (Mirko et al., 2019).

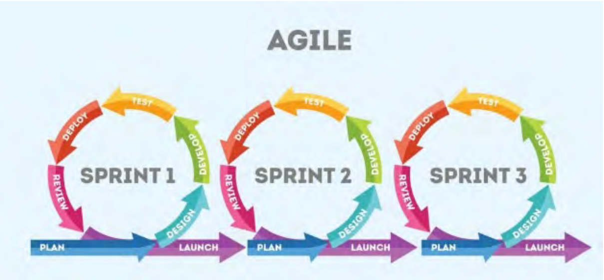

Figure 2: Agile Development Model (Sapna, 2022)

Before the actual development of the project, a clear and precise project plan is required under the agile development method as the method aims to break tasks into smaller iterations that do not directly involve long term planning for easy management. Therefore, a meeting with major stakeholders of this project was conducted including industrial partner, NGO&NPO and potential users in order to lay down the clear and precise project scope and requirements at the beginning of the development process. The meeting also clearly defined the number of iterations, the duration and scope of each iteration. After the meeting, a preliminary project plan was produced. There is a total of 11 iterations in the project and each iteration last for 4 weeks. Each iteration is also divided into two sub-iterations, for example of iteration 1, it has two sub-iterations, 1A and 1B. For the A iteration, technical meeting with industrial partner was conducted in order to confirm the output of this iteration and then student will start to implement the project protype of this iteration with the support from industrial partner, the A iteration last for 3 to 3.5 weeks depending on students' school schedule. B iteration will start right after the end of A iteration, NGO&NPO and potential user will involve in this iteration and to give comment based on students' project prototype to see whether it fits the needs of the potential users. The comments received from this iteration will become the input of next iteration and so on, which helps the quality of the project evolution throughout each iteration. Table 1 shows the summary of agile iteration of this project.

Table 1: Summary of agile iteration

Date	Iteration Number	Iteration Content
SEP 2021	1	A. Technical meeting with industrial partner & prototype implementation (last for 3 to 3.5 weeks) B. Project prototype showcase to industrial partner, NGO&NPO, and potential user
OCT 2021	2	
NOV 2021	3	
DEC 2021	4	
JAN 2022	5	
FEB 2022	6	
MAR 2022	7	
APR 2022	8	
MAY 2022	9	
JUN 2022	10	
JUL 2022	11	

Coronavirus issues is the important factor needs to be noticed throughout the project period. The project was started during the coronavirus period, and students were suggested to study online class at home and not allowed to back to school unless special approval in order to minimize the chance of infect. In other words, students can only communication with academic supervisor and industrial partner, and other stakeholders through video conferencing software such as Microsoft Team. Due to the pandemic situation in Hong Kong in 2021-2022, the face-to-face learning activities were limited. The NGO&NPO partners organized two activities for students understand the needs of the elderly and meeting with potential user in person which allows students to collect feedback from them directly to fine-tune the function of the project prototype. For example, the NGO&NPO organized a guided tour for students to visit Elderly Resources Centre of Hong Kong Housing Society as shown in figure 3, and a meeting with potential user in person as shown in figure 4. Through the event, students can explore more to the society, and they had a valuable opportunity to meet with potential user in person and to collect feedback from their side directly. Thus, students were able to find out more precise requirements of elderly apart from their initial idea and students would then be able to design and develop elderly-friendly and cost-effective related solutions. Table 2 shows the summary of the project details and collaboration framework.

Table 2: Summary of the project details and collaboration framework

Project Duration	12 months SEP 2021 to AUG 2022
Project area	Artificial Intelligence based Healthcare System
Project Team	4 SE students from institute 1 industrial partner 1 NGO&NPO partner
Software Development Model	Agile Model
Number of iterations	11
Duration of each iteration	4 weeks

Figure3: Visiting Elderly Resources Center of Hong Kong Housing Society

Figure 4: Meeting with potential user in person

Collaboration Result

The project has been completed successfully on August 2022 with the support from industry and NGO&NPO. All tasks listed on the project scheduled were completed successfully on time with no delay. The project team submitted the project prototype to join different ICT competitions in Hong Kong, which aims to receive valuable comments from the professional judges in order to know the rooms of improvement of the second version of Self-Phy. Finally, the project was received four awards in two public competitions in Hong Kong. The details are as follows:

1) Hong Kong Housing Society (HKHS) Gerontech Competition 2021/22: Gold Award, Best Creativity Award, Best Application Award

2) The Greater Bay Area STEM Excellence Award 2022 (Hong Kong) - A.I. Stream: Gold Award

Figure 5: Award ceremony of Hong Kong Housing Society (HKHS) Gerontech Competition 2021/22

Figure 6: Award ceremony of the Greater Bay Area STEM Excellence Award 2022 (Hong Kong)

Because of the outstanding achievements of the project, the project team was also invited by the famous media in Hong Kong to join TV interview to introduce their project to the public and share their development experiences. The TV interview includes "Happy Old Buddies" on 29 September 2022 and "Innovation GPS" on 5 January 2023.

Figure 7: Screenshot of "Happy Old Buddies" on 29 September 2022

Figure 7: Screenshot of "Innovation GPS" on 5 January 2023

As discussed in the last section, the expected duration of the project is between September 2021 to August 2022. After received outstanding results in two ICT competitions and positive comments from the industry leader and professional judges, the project team decided to turn their idea to a real business. Four students established their own start-up company to further develop the second version of Self-Phy, which aims to provide HealthTech solutions to elderly people in order to reduce the pressure of health care system of Hong Kong and to make our society better, and the most important thing is that students could use their knowledge learned from school to give back to the society. The project was also admitted to the ideation programme of the Hong Kong Science and Technology Park (HKSTP) and received HK100,000 financial grant to support their company development, with one-year startup all-round support from designing a business model to finding investment and provide mentor for business advice.

Discussion

This study proposed a collaboration framework between institute, industry and NGO&NPO in developing healthcare system during the coronavirus period. Despite the project was completed successfully and obtained outstanding results, we believe that there is still room for improvement in future to enhance the quality of engineering education. Therefore, at the end of the project, an interview section with students, industrial partner and NGO&NPO was conducted in order to collect feedback and best practice of this collaboration.

After interviewing with stakeholders, it was found that from the perspective of industry and NGO&NPO, they are more preferring to provide support to student through the online meeting as they have time constraints because of their busy work schedule. With the adoption of online meeting, it can reduce the traveling time for industrial partner to travel form their company to the meeting site. The saved time could be used to provide more support to students. Second, from the perspective of students, even though the adoption of online meeting can save the traveling time, they reported that their sense of belongings of the project will be increased if they can report to the industrial partner and NGO&NPO in person at least once per month.

Before the pandemic, we did not imagine and explore the possibility to conduct project across the Internet. In the past, we just consolidate a common time for all project team members and then reserve a meeting venue before the meeting with project stakeholders in person. We spent a lot of time in the preparation of a face-to-face meeting and the traveling time as well. What if we can optimize the time spent in the preparation of meeting?

In the post coronavirus era, it is suggested that we can adopt bi-iteration approach to conduct the project collaboration, which means a face-to-face iteration comes first followed by an online iteration and so on and so forth. The main reason of why it is not suggested to keep everything online is that the sense of belongingness of students and other stakeholders to the project will be dropped a lot. Moreover, in order to balance the feedback from the students and industrial partner, it is also recommended that students could stay at industrial partner' workplace one to two times per week to implement the project according to the school schedule and industrial partner's schedule in order to let students experience life in the workplace which is beneficial for students to better prepare themselves to be an outstanding employee after graduation. Other institute in Asia regional may try to adopt the framework introduced in this study and the suggestion above or adapt the framework according to the culture of the country in order to better training for the next generation.

Limitation and future directions

In this study, there are some limitations that should be acknowledged, so that the research results can be interpreted with necessary caution. First, the research framework only tested on the area on Artificial Intelligence-based intelligence products, services, and systems, while other subject area may not be able to adopt the framework directly. Pointing to the limitation of this study, further research directions can be based on the framework proposed in this study, researchers can further explore and develop framework to adapt to the fast-growing ICT environment and conduct additional research to adapt the framework of this study according to the subject area, and to compare and evaluate the performance between newly developed framework and other collaborative framework.

Conclusion

In conclusion, the adoption of PBL and collaboration between academic, industry and NGO&NPO can address the societal needs and enhance the quality of engineering education, as demonstrated by the Self-Phy project. This paper presents the project details of Self-Phy, discuss the collaboration framework of Self-Phy between institute, industry and NGO&NPO during the coronavirus period, and to propose a post corona virus era collaboration framework. This study also highlighted the importance of developing a strong relationship between three parties by showing the Self-Phy project. It is convinced that the collaboration between three parties does bring more advantages than disadvantage to student and help institute produce quality graduates who can full fill the manpower needs in the job market and satisfy their future employers need.

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ENHANCING PASTORAL CARE AND ACADEMIC MONITORING EFFORTS USING THE AiE-PFP LEARNING ANALYTICS SOLUTIONS

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Abstract

This paper describes the journey undertaken by a 5-polytechnic project team in collaboration with an external vendor in Singapore to produce 2 learning analytics (LA) solutions in education, a predictive model and a personal tutor facing dashboard. The predictive model generates projected learning needs of students by running machine learning and statistical rule-based algorithms through data such as attendance rates and past academic performance. The dashboard then displays the projected student learning needs as well as other pertinent information about the students such as choice order of diploma, academic performance progress, participation in co-curricular activities (CCAs), and other behavioural indicators. The intent of the LA solutions is for personal tutors (lecturers who take care of pastoral care and academic needs of students) to be able to glean insights and devise and apply appropriate interventions based on the data presented. With better support and interventions, it is hoped that student academic outcomes will be optimised.

After the 1-year pilot which involved 104 personal tutors of 5 polytechnics, a comprehensive evaluation exercise was conducted amongst the students and personal tutors to ascertain the effectiveness of the LA solutions. Reception amongst both students and personal tutors was generally positive. Personal tutors found the LA solutions to be helpful in getting to know their tutees better and identifying areas that require support. Students perceived that their personal tutors had provided them with sufficient pastoral care and guidance. A task analysis exercise that measured time spent before and after using the LA solutions also revealed that, after the implementation of the dashboard, personal tutors can save time not having to consolidate data from disparate sources on their own accord.

The successful pilot led to a second phase of the project, which is to implement similar LA solutions to other diploma courses.

Keywords: *learning analytics, predictive model, dashboard, personal tutors, student learning needs, interventions*

Introduction

In recent years, there has been growing interest amongst institutes of higher learning (IHLs) to adopt learning analytics solutions to enhance student learning experience. Due to this interest, the 5 polytechnics in Singapore undertook a project to explore the use of learning analytics in education in 2019. 2 learning analytics (LA) solutions resulted from the project - a predictive model (PM) that produces projected student learning needs and a personal tutor (PT) facing learner profile dashboard (LPD). In this paper, we will start by describing the development and implementation process of the LPD and PM. The authentic use of the solutions by a PT to support her tutees is elaborated before we present evaluation outcomes. Future work will also be discussed.

Method

Polytechnic Foundation Program (PFP) is a 1-year bridging program for outstanding Normal Academic stream graduates to be admitted into polytechnic diploma courses, without taking O level examinations. In this program, students take modules that are prescribed by Singapore's Ministry of Education (MOE), such as English and Mathematics, and domain-specific modules such as IT, Chemistry and Business. PFP students must pass all modules before they can advance to their chosen diploma courses.

The LPD and the PM were developed with the PFP PTs in mind. Each PT is assigned a class of about 20 PFP students as tutees and they are tasked to guide and mentor their tutees throughout the PFP year, in academic and non-academic aspects. Hence, it is essential that the PTs are well-supported in their role with data and analytics tools, in order that they can do their job well.

Guided by the principle that LA solutions should focus on problem statements and needs of the users, (Michos, Lang, Hernandez-Leo & Price-Dennis, 2020; Demmans Epp, Perez, Phirangee, Hewitt & Toope, 2019) who are the PTs in this case, the project regularly consulted the PFP team on problems they commonly encounter while running the program. The LA solutions were then developed to address those problems. Subsequently, iterative discussions were held with the users to refine the solutions throughout the development process. This user-centric approach aimed to improve usage and adoption of the solutions (Denmans Epp et al., 2019; van Deen et al., 2019; Daley et al., 2020).

The LPD and PM were developed to answer the following problem statements (PS) of PFP PTs.

PS1: What is the socio-economic and academic background of my individual students?

PS2: Individually, who are likely to be in the A, I or E group at the end of PFP year and why?

PS3: How do the various groups of students (A, I or E) progress academically throughout the PFP year?

In the problem statements above, the “A” group refers to PFP students who perform at the top of the cohort, the “E” group refers to those who perform at the bottom and the “I” group includes all the rest.

A 5-polytechnic project team was formed to work with a vendor to produce the LA solutions. The project team comprised of representatives from functional, pedagogical and technical areas. The team members worked closely with the vendor in various aspects of the project such as requirements gathering, data assessment, design and development as well as user testing.

Predictive Model (PM)

Historical data from the last 7 PFP cohorts were used to train the model. To ensure sufficient accuracy of the model, the *k*-fold cross-validation method was carried out because it is widely used when data is limited (Dantas, 2020; Brownlee, 2020). 4 models were developed to predict outcomes of PFP students, in Science & Technology and non-Science & Technology tracks, using pre-polytechnic as well as in-polytechnic data, at the beginning of each of the 4 PFP terms. The models that were ultimately assessed to be most accurate for adoption were logistic regression models that use student data such as pre-polytechnic N level results, in-polytechnic attendance rates, academic performance consistencies and key subject results as predictors.

Learner Profile Dashboard (LPD)

In building the dashboard, the functional representatives from all 5 polytechnics regularly gave their inputs in areas such as data attribute requirements, visualization designs and placements and interactivity of dashboard. An expert dashboard designer was also involved to give recommendations on best practices of dashboard design. This helped to smoothen and expedite the development process.

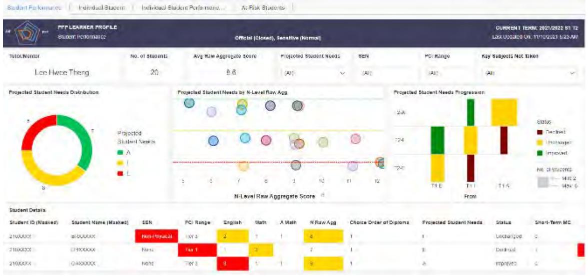
The LPD comprises of 4 pages, namely the Student Performance (SP), Individual Student (IS), Individual Student Performance (ISP) and At-risk Students (AR), which are interactive with drill-through from one page to the next. It consolidates and displays rich information on student profiles using data from disparate sources such as student administrative system, file uploads, learning management system as well as projected student needs via the PM. Controls were also built in to ensure proper role-based data access, as this is a requirement of Model AI Governance Framework (World Economic Forum, 2020).

Implementation

In April 2021, the LA solutions were rolled out to all 104 PFP PTs of the 5 polytechnics. Users had to be adequately trained to ensure they utilize the LA solutions in a manner that abides by the Model AI Governance Framework. Before the term started, the PTs attended a hands-on training session to learn how to navigate the dashboard, interpret the data and handle the data responsibly. They discussed how they could use the insights from the LA solutions to devise appropriate interventions. Halfway through the term, another training was conducted to enhance their understanding of how the PM works. The PTs were briefed on the algorithm that drives the model, how to interpret accuracy statistics of the model and propensity scores, and the explainability of the PM. This knowledge is necessary as the LA solutions were designed to involve “human-in-the-loop" whereby user interpretation and decision-making play a vital role. At various milestones of the PFP year, the PTs were prompted to use the LA solutions as needs arose. Instances of such milestones include Meet-the-Parent session at mid-year and individual student counselling after major assessments. Besides formal trainings, PTs were frequently engaged in dialogues and communications that enhanced their awareness of institutional and personal benefits that the LA solutions offer. It is desired that such engagement will motivate some of them to become LA champions in future (Ferguson & Clow, 2017).

The Learning Analytics Solutions

The 4 pages of the LPD can be seen in Figure 1 below.



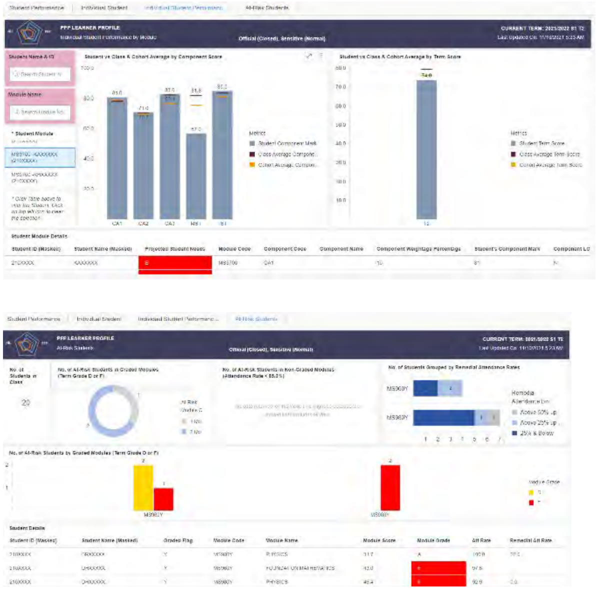


Figure 1. PFP LPD comprising of 4 pages: (First) *SP* page; (Second) *IS* page; (Third) *ISP* page; (Last) *AR* page

SP page: This page provides student details at the class level such as socio-economic and academic background. It also displays PM results, allowing the PTs to identify students who need different levels of support. This page is useful for PTs to get to know the class better and offer early support and assistance at the beginning of PFP. This addresses PS1 and PS2.

IS page: This page provides information at the student level such as academic performance and attendance for all the modules taken in the term. This page is useful for PT to drill down to a particular student to monitor his/her performance for each module and compare that to the class and cohort. PTs can then provide counselling to students who are struggling academically on how to better manage their time and optimize their learning strategy to improve their academic performance. This addresses PS2 and PS3.

ISP page: This page provides information at the individual student-module level. PTs can view each student's academic performance in every assessment component of each module. In instances where student performed inconsistently across different assessment components, PT stepped in to address the issue in a timely manner, for instance by offering advice on how to handle examination jitters. This addresses PS2 and PS3.

AR page: This page serves as a diagnostic tool for PTs to conduct counselling to poor-performing students. It highlights to PTs information such as number of modules that students are doing badly at, students who are missing lessons and remedial lessons. This addresses PS2 and PS3.

A PT's Use Cases

The following sections will elaborate about how one PT, Diana, utilised the LA solutions. Diana has more than 10 years of teaching experience but is relatively new to the role of PT.

At the start of PFP, Diana used *SP* page before meeting her tutees. From the dashboard, she was able to tell the following.

1. The class was of average academic ability as the average N level raw score was 8.6 (raw score is between 5 and 12, with 5 being the best and 12 being the worst score). Diana decided to adopt a medium-paced teaching speed.
2. There were 6 tutees in the class who were projected to be in the "E" group. Diana would want to closely monitor these 6. She held one-to-one conversations with them to establish rapport and offer support early in the term.
3. There were 3 tutees with declared Special Education Needs (SEN). Diana checked-in with them if they wanted to request for special learning support such as time extension during major assessments.
4. 8 students did not take Additional Math in secondary school. They might struggle in PFP math module and since Diana was their math lecturer, she offered remedial sessions to them.
5. 1 student was offered his 5th choice of diploma. As a result, the student may not be motivated to work hard in his studies. Diana kept a closer watch and provided education and career counselling to the student regularly.
6. Based on the per capita income (PCI), 9 students could benefit from financial support. Diana offered them bursary or laptop subsidy applications as assistance.

During the terms, Diana used the LPD to monitor the overall attendance and academic progress of her tutees in individual modules. Such information allowed her to check-in with tutees, as well as module lecturers, when potential issues were detected.

The LPD provided information about the tutees without Diana having to scroll through one student at a time via the student administration system. In one glance, Diana was able to gauge the academic and background profile of her class as well as monitor them as the term progressed. She could then decide on the appropriate teaching and pastoral care approaches early on. As she became more aquainted with the tutees, she could then adjust her approaches to suit their needs. She could also identify the modules that her tutees were struggling in and worked with the module lecturers accordingly.

Use case 1: "Struggling Sarah"

Sarah was admitted into PFP with a decent N level aggregate score of 7. She was offered her first choice of diploma and was predicted by the PM as "I" student at the beginning of the program. Based on her background information, she would have been expected to succeed in the program. As the term progressed, however, Diana noticed, from the *IS* page (Figure 2), that Sarah was not attending lessons regularly, particularly for one module. Diana contacted the module lecturer to find out more about the situation. She then counselled Sarah and highlighted repercussions of low attendance. She also sent reminders to Sarah to attend class, especially those that started early in the day.

The module lecturer also monitored Sarah and provided regular feedback to Diana on Sarah's progress in the module.

Despite all the efforts, at the end of Term 1, the *IS* page (Figure 2) showed that Sarah was performing badly in many modules. She failed 3 modules and scored significantly below cohort and class averages in others. Diana arranged to meet Sarah's parents to inform them of Sarah's academic performance and to discuss interventions to help her. Diana also found out from her conversations with Sarah that she was facing anxiety and motivational issues that prevented her from putting in her best efforts in her studies. Sarah was thus referred to the polytechnic counsellor to help her cope with her anxiety issues. She was also assigned for remedial lessons for the modules that she was not performing well. Diana hoped that the holistic approach would help Sarah.

Eventually, Sarah managed to complete PFP although her academic outcomes were below average.

Figure 2. Sarah's low module attendance and poor module performances as flagged out by *IS* page

Use case 2: "Declining Dave"

Dave had been an outstanding student throughout the first 3 terms of PFP. He entered PFP with a score of 9 and was posted to his second diploma choice but had been attending class regularly and doing well in his past assessments in all modules. In fact, he was doing so well that the PM projected him to be "A" student in terms 2 and 3, an improvement from the initial "I" projection in term 1. He was also a responsible class representative.

Diana was thus surprised that in the beginning of term 4, Dave was projected as "I" student, a decline from term 3 (Figure 3). From the *IS* page (Figure 4), she realised that Dave was doing well in modules such as Math, Physics and Applied Science, but not as well in language modules. When she drilled into the component assessment scores of the module through the *ISP* page (Figure 5), it appeared that Dave was struggling with report writing assignments of the module.

Diana arranged a chat session with Dave to find out more. She started by commending him on being an excellent class representative and on doing well in his Math, Physics and Applied Science modules. She then queried on his poorer performance in language modules. Dave's responded that he found it challenging to do report writing as he had always struggled with English. He highlighted that he had scored a B3 for English at N levels, which is the poorest possible grade for English to be eligible for PFP. Diana encouraged Dave to check with the module lecturer on ways to enhance his report writing skills. She also encouraged him to search for online resources to learn how to write better reports. Dave was receptive to these suggestions and promised to put in effort to improve.

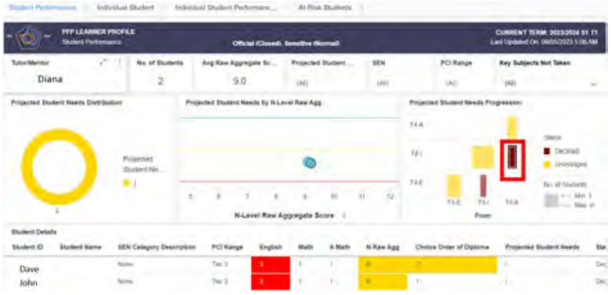


Figure 3. Dave's projected student needs went from "A" in Term 3 to "I" in Term 4 as seen on *SP* page

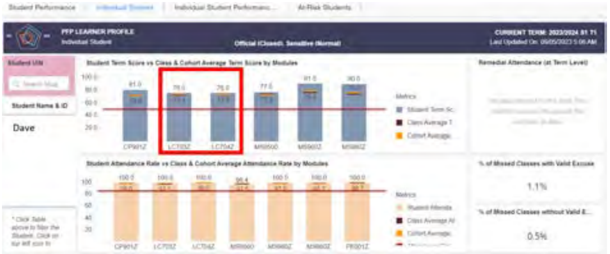


Figure 4. From *IS* page: Dave's performance in language modules was not as good as that in other modules

Figure 5. From *ISP* page: Dave scored below class and cohort averages in writing assessment components

The 2 use cases showcase the usefulness of the LPD in identifying struggling students as well as students who could be nudged towards greater achievements. In the case of Dave, previously, without LPD, Diana will not have noticed that decline in performance as readily. Often, timeliness of appropriate interventions is essential to optimise the learning outcomes of students. With the LPD, PTs can intervene more effectively and efficiently.

Findings

To evaluate the project holistically, various evaluation methods were adopted to capture feedback and opinions of the PTs and the students.

Staff Survey

The *Technology Acceptance Model (TAM) Survey* was administered to all PTs who participated in the project.

TAM, developed by Davis (1989), is a widely used model to explain usage and acceptance of technology and information systems by individual users. Feedback was collected on PTs' experience in the following 6 aspects:

i. *Perceived Usefulness* indicates the extent of the user's belief that using a specific system would enhance his or her job performance. More than 87% of respondents agreed that using the LPD would enhance his or her job performance in all 6 questions.
ii. *Perceived Ease of Use* indicates the extent of the user's expectation that using a specific system would be free of mental and physical efforts. More than 81% of respondents agreed that using the LPD would be a relatively effortless affair in 3 out of 5 questions.
iii. *Trust* defines the confidence placed by the user on the system and forms the disposition towards the use of AI-assisted technologies. More than 93% of respondents trusted the LPD in all 3 questions.
iv. *Anxiety* defines the extent of the user's fear or apprehension, when exposed with the possibility of using a system. More than 81% of respondents did not feel apprehensive when using the LPD in all 3 questions.
v. *Relative Advantage* reflects the user's perception of the benefits of using a specific system in comparison with other existing alternatives. More than 81% of respondents agreed that using the LPD is better than using existing data systems in all 6 questions.
vi. *Behavioral Intention to Use* is the extent of the user's intention to perform or not perform some specified future actions. More than 87% of respondents agreed that they intend to use and will recommend others to use the LPD in 2 out of 3 questions.

The responses were very positive and a summary of the survey results from the 26 questions is shown in Table 1 below.

Table 1: TAM Survey Outcomes

Responses	Perceived Usefulness	Perceived Ease of Use	Trust	Anxiety (Negative Construct)	Relative Advantage	Behavioral Intention to Use
Strongly Agree / Agree / Somewhat Agree	91.67%	81.25%	95.83%	18.75%	91.67%	83.33%
Strongly Disagree / Disagree / Somewhat Disagree	8.33%	18.75%	4.17%	81.25%	8.33%	16.67%

Task Analysis

The intent of conducting *Task Analysis* is to offer a measurement of the possible time savings arising from the LA solutions implementation. 2 PTs and 1 Course Chair participated in the task analysis. Based on guiding use cases, they completed a set of 20 contextualized tasks before and post implementation of the LPD. The following were logged during the analysis for both pre and post task analysis sessions:

i. No. of tasks that can be completed by the participants
ii. Time taken to complete those tasks
iii. Systems used to obtain the required information

The findings from the task analysis suggested that there is time savings of about 281 hours per academic year. It also proved that, with the LPD, PTs and Course Chair can complete all the information gathering tasks independently instead of using multiple systems or requesting for assistance from other colleagues. The aggregation of relevant information in LPD helps to streamline processes and improve work efficiency.

Focus Group Discussions

All the PTs involved in using the LPD were invited to attend 4 focus group discussions (once per term) to solicit their feedback on user experience. During the discussions, the LPD was evaluated in the areas of implementation issues, ease of usage, actionable insights and student outcomes. Generally, all users felt that the dashboard is useful and provides them with additional insights of the students. There was also sharing of good practices and narratives of how users were making use of the dashboard to devise interventions.

The findings from the discussions were aligned with the *TAM* survey results:

i. *Perceived Usefulness* (91.67%): From the various sharing of how different PTs utilized data from the LPD for interventions such as recommendation for remedial lessons, individual counselling with different focuses based on different student profiles, we can infer that PTs find the dashboard useful.
ii. *Perceived Ease of Use* (81.25%): Perception of usability improved over time when the PTs gradually got used to the dashboard. They have also shared challenges and provided recommendations to improve ease of use. One suggestion was to pace out the training content into bite-sized chunks to enable better learning of navigation of dashboard.
iii. *Trust* (95.83%): From the sharing of how PTs use information from LPD to prepare their dialogues with various stakeholders, it can be inferred that PTs trust the data. PTs also trust LPD enough to use it as a diagnostic tool to plan intervention actions.
iv. *Relative Advantage* (91.67%): It is evident that PTs prefer using LPD over their existing processes as they commented on how they are now able to access all the important data without having to log into separate systems. The amount of time saved is a huge benefit afforded by the dashboard.
v. *Behavioral Intention to Use* (83.33%): When asked how they can be motivated to use the dashboard more, some PTs requested for more functionalities and data such as alerts to at-risk behaviors and LMS data. They commented that as the terms progressed, their usage declined as they have built sufficient understanding of their students. As such, most of them will recommend the dashboard to other users, but to encourage higher frequency of use, more dynamic data will have to be included.

All of the PTs agreed that the teacher (human-in-the-loop) is critical in using the solutions. PTs primarily used the dashboard as a reference to confirm teacher's own observations of the tutees before carrying out interventions.

"As a PT, I have pastoral practice with my students called Heart-to-heart-talk (H2HT) every 2-3 weeks.

I will meet different students on different days, depending on their breaks.
I use this dashboard to understand my students' backgrounds to kickstart h2ht. Previously the H2HT is more generic which we talk about how are they settling in and students usually say they are ok. But now, with the dashboard, I can jump straight into using PCI to talk about financial help. And from there I was able to suss out one student whose parents lost their jobs and as they have zero income. I followed up by asking him how he feels. This really opens up conversations. Previously happen after term 1 due to lack of pre-poly data. But now able to bring it forward to first few weeks of Term 1."

Student Perception Survey

PFP students were polled on whether they feel that they have been adequately supported by their PTs with 8 quantitative questions (Myint, S. K., 2001). On average, 79% of the PFP students gave positive ratings (Table 2). This indicated that the students acknowledged the great care and support offered by their PTs. It also affirmed the PTs' narratives during the focus group discussions that they had used LPD to better support their tutees.

Table 2: Student perception survey outcomes

Question	Average Rating (out of 5 points)	Positive Rating
Q1 The personal tutor cares for my well-being	4.34	83.3%
Q2 The personal tutor cares for my learning	4.44	89.6%
Q3 The personal tutor goes out of his/her way to help me	4.23	79.4%
Q4 The personal tutor considers my feelings	4.26	81.5%
Q5 The personal tutor helps me when I have trouble with the work	4.35	84.0%
Q6 The personal tutor talks with me	4.08	71.8%
Q7 The personal tutor is interested in my problems	3.86	62.4%
Q8 The personal tutor's questions help me to understand	4.21	79.4%

Results and Future Work

The reception to the LA solutions was promising and the pilot proved to be a successful one. The team continued to refine the LPD by incorporating easily accessible user guides and intervention suggestions. Another module lecturer dashboard was also developed using dashboard templates.

This pilot has provided a glimpse of an exciting analytics and data journey for educators in the future. The vision is that all lecturers will be armed with meaningful data and analytics tools that allow them to execute teaching and learning decision making in a data-informed manner. Plans are underway to roll out similar LA solutions to other diploma courses in the 5 polytechnics.

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Issues in device development education in collaboration with medical institutions

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Abstract

In collaboration with engineering educational institutions and medical institutions, we are providing manufacturing education that cannot be experienced only on campus through the development of medical support equipment. After trial and error, we established a curriculum as an assistive technology course with six units as one package. This course consists of 2 units of classroom lectures and 4 units of seminar subjects. However, it is a special course in addition to the curriculum of the conventional department, and the students feel a heavy burden. This is a common problem in many manufacturing subjects. During class time, it is necessary to have time to be conscious of today's goals based on the results of the previous session. In addition, time to prepare for work and time to clean up at the end are necessary. Therefore, the amount of time spent on manufacturing is very limited during class hours. As a result, students are also required to engage in extracurricular activities. This is the reason for the low number of participants.

Based on these, we will clarify the significance of this special course and discuss the results of examining solutions to these issues. In the manufacturing of medical-engineering collaboration, it is important to first create prototypes for discussion and to embody the issues for quantifying the design specifications. In addition, in order to maintain the motivation of students, it is important not to embody the idea as the goal, but to conduct a demonstration experiment with the product and evaluate the effect quantitatively. In addition, we will discuss the importance of close cooperation between medical and engineering coordinators, production staff, and staff in the medical field, as well as quantitative evaluation criteria as the final goal.

Keywords: *different needs from three standpoints, prototype, masked needs, endless development, quantitative evaluation criteria*

Introduction

In the field of hands-on education, there has been an increasing focus on two-dimensional (2D) fabrication methods such as problem-solving through programming and design using three-dimensional computer-aided design (3D CAD). In the real world, the use of 3D CAD is becoming mainstream in order to omit the mockup production process and simplify trial and error, so it is important to incorporate manufacturing using such tools in educational settings. However, I think there are prerequisites for this. In other words, when people who are manufacturing or who have experience of manufacturing are promoting manufacturing with each other, using these tools is effective in various ways, such as shortening time and enabling sufficient discussion.

On the other hand, it is very important for students who have little experience in manufacturing to know how difficult it is to give shape to their ideas, that is, to embody their ideas. In this paper, "manufacturing" is defined as "problem solving with a clear purpose and a set goal."

"Manufacturing" and " Crafting" are different. Crafting is the realization of ideas through processing and assembly, while manufacturing is the determination of design specifications, the proposal of solutions that satisfy those specifications, and the definition of problem solving through the realization of these proposals. Furthermore, manufacturing is the simplest when there is only one target for the creator to consider. In other words, the target purchases and becomes a user. For example, make a pencil for writing or a cup for drinking. In such cases, the problem is solved if the purpose of a pencil that writes easily, a cup that does not leak, etc. is achieved. Next, there are two types of target users. For example, school bags. In this case, the purchaser is the presenter, such as a parent, and the user is the child. As a result, design specification conflicts are increasing. For example, a contradiction in purpose arises, such as things that are heavy but cheap rather than light and strong. In addition, in the case of manufacturing through medical-engineering collaboration, another point of view increases. In other words, users have different needs, such as business operators, patients (users), and purchasers (facility/maintenance side). And conflicting problems become a three-way street.

In order to carry out manufacturing (problem solving) that satisfies such needs, there are several issues that must be overcome. However, tackling such high-hurdle issues has a highly effective aspect as manufacturing education.

In this paper, we discuss issues related to development education in medical-engineering collaboration based on our previous experience. We then provide what we have learned about what it takes to overcome the challenges of incorporating this meaningful medical-engineering device development education into the curriculum.

Education curriculum

We offered a two-year, six-credit training curriculum for device development in collaboration with medical institutions. Each unit consists of 15 sessions and each session is 90 minutes. The first year is 1 credit for lectures and 1 credit for seminars. In the second year, 3 credits of exercises and 1 credit of lectures are offered. These five subjects are as follows:

(1): Introduction to Assistive Technology: IAT,
(2): Practice in Assistive Design: PAD,
(3): Practice in Clinical Equipment development: PCED,
(4): Assistive Technology and Co-op: CPAT,
(5): Introduction to Medical Welfare Technology: IMWT.

IAT : Introduction to Assistive Technology

In the IAT course, the curriculum focuses on gaining a physiological understanding of disabilities and learning approaches to functional compensation. The program has set the following three objectives. (1) Regarding welfare devices, there are cases where the needs to be addressed may conflict among the purchaser (management), operator (caregiver), and the individuals directly involved (patients) who have physical contact. Understanding and being able to explain what constitutes an "usable product" in light of these perspectives and developing products accordingly. (2) Acquiring knowledge of human characteristics (ergonomics) and understanding and explaining their applicability to future development and other areas.
(3) Understanding and explaining how the shape of objects and the work environment can affect the human body differently.

PAD : Practice in Assistive Design

In the PAD course, students collaborate with medical institutions to generate ideas and receive feedback from the field in response to their needs. The course has set the following three objectives. (1) Understanding the engineering process and being able to generate problem-solving proposals that incorporate fail-safe and foolproof considerations. (2) Delivering presentations that are understandable and convincing to non-engineers.
(3) Generating ideas from the perspectives of three types of customers (end-users): the purchaser, operator, and individuals who directly benefit from the assistive technology devices.

PCED : Practice in Clinical Equipment development

The PCED course applies and improves the knowledge gained in the PAD. Bring your ideas to life through functional prototyping. This course has three goals: (1) Enhancing existing designs with industrial design elements while meeting the required functionality. (2) Understanding and incorporating fail-safe and foolproof principles into the design process. (3) Building functional prototypes and preparing comprehensive reports documenting the development process.

CPAT : Assistive Technology and Co-op

In the CPAT course, the products developed by PCED are used in cooperation with medical institutions, evaluated, and further improved. It is also intended to be re-evaluated and brushed up. This course has three goals:
(1) Understanding and applying the experimental planning based on the "Ethical Guidelines for Medical Research Involving Human Subjects" to conduct product evaluations in actual medical settings. (2) Understanding and utilizing the non-verbal communication effectiveness between the developed products and the clinical environment.
(3) Being able to consider improvements based on evaluations and checks.

IMWT : Introduction to Medical Welfare Technology

In the IMWT course, students gain hands-on experience in creating products for clinical settings and learn about the development of project proposals, experimental plans, and other related documents. The course has set the following four objectives.
(1) Understanding and applying the social security system in Japan. (2) Understanding the symptoms of diseases such as dementia and recognizing the considerations that need to be taken into account to address associated social issues. (3) Understanding the concept of biofeedback and being able to apply it.
(4) Understanding the specifications and quality assurance in the development of welfare and medical devices and being able to apply them.

Device Development through Collaboration between Medical and Engineering Fields

In this section, we will explain the development of a detachable voice input nurse call device as a case study conducted through collaboration between PAD, PCED, and CPAT.

Background of the Development

Nurse call devices are commonly used to connect caregivers and nurses with patients, especially those with severe limb paralysis. However, the widely available nurse call systems are typically button-operated, which poses difficulties for individuals with cervical spinal cord injuries who have limited hand movement. Consequently, patients with cervical spinal cord injuries resort to alternative methods such as breath-activated switches or point-touch switches. Nevertheless, these switches require precise positioning adjustments to accommodate the patient's subtle movements, resulting in the need for frequent readjustments during caregiving. Therefore, there is a demand for a simple method that allows patients with cervical spinal cord injuries to operate nurse call devices without relying on hand movements or breath activation.

In recent years, inclusive design principles, considering the usage by minority groups, have been increasingly applied in device development. AI speakers, which have become more affordable and are widely used in households, are an example of this trend. Building upon this, Suzuki et al. [1] developed a voice-activated nurse call device that can be operated both through voice commands and manual interaction, without modifying the existing nurse call systems in hospitals. In a preliminary study, a self-controlled study was conducted comparing the developed device with point-touch switches traditionally used by cervical spinal cord injury patients. The evaluation criterion was the setup time of the development machine and the reference machine. Ten rehabilitation staff members in charge of environmental preparation participated in this study. As for the experimental procedure, we prepared the device until the simulated patient could initiate a nurse call, and conducted a comparative test using the developed device and the conventional device. The staff who participated in this comparative trial suggested that there is a possibility of changing to a positive response to the introduction of AI speakers. This indicates the importance of inclusive design that considers not only users but also operators.

However, the average setup time for the developed product was 78 seconds, which was 1.5 times longer than the results of the comparative test. Therefore, improvements in devices that are easier to set up have been found to be necessary.

Development Objective

The purpose of this development is to replace the existing nurse call system without tools and without the need for advance directives from nurses. Also, it is to develop a device that can be installed within 50 seconds. The device should allow for both voice and manual operation, facilitating use in a variety of hospital rooms.

Design specification

The design specifications are as follows.
(1) The overall dimensions of the device must fit within the desktop space of 100mm x 100mm. (2) It must be able to respond to various types of nurse calls within hospitals. This means broad compatibility with existing nurse call systems. (3) Easy installation without tools. In addition, the burden on healthcare workers should be minimized. In other words, the target installation time until nurse call activation by voice operation is within 50 seconds.

Result: Developed device

Figure 1 shows the developed and manufactured device. This device allows for direct manual activation of the nurse call button. Additionally, it incorporates a solenoid for operating the nurse call via voice commands. The device includes a clamp for adjusting the mounting position of the solenoid and nurse call. The plate shown in the figure is a clearance plate designed to facilitate easy adjustment of the mounting positions of the solenoid and nurse call. Figure 2 presents the equipment used and the operational flow. For the voice-activated nurse call, the AI speaker used is the Google Nest Mini (98mm in diameter, 42mm in height). A hub mini (65mm in height, 65mm in width, 20mm in height) is used as a substitute for a remote control to transmit the voice signal to the solenoid via Bluetooth. To activate the nurse call using the AI speaker, the user needs to say "OK Google, turn on the nurse call."

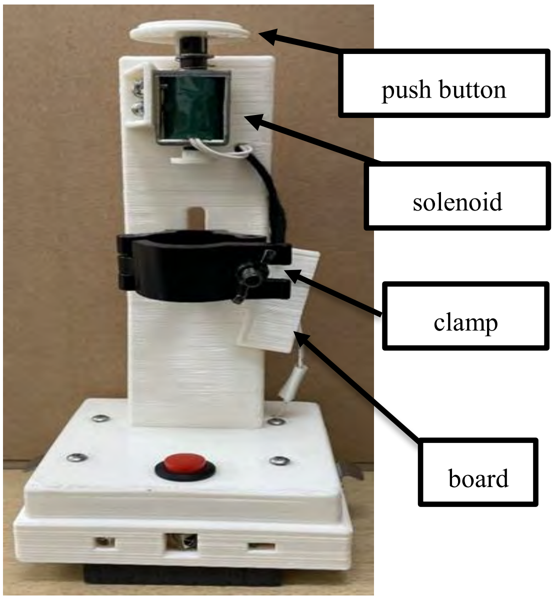


Figure 1 Developed equipment

Innovations and Improvements for Time Reduction during Installation

When patients are changed or rooms are switched, it becomes necessary to attach the device to the nurse call system beside the bed. In such cases, it is crucial that non-engineer nurses can easily set up the device without receiving instructions. To address this, a card illustrating the installation and operation methods, as shown in Figure 3, is affixed to the device itself. This eliminates the need to search for a manual or memorize the installation process, making it easier for nurses to set up the device.

Figure 2 The equipments used and the flow of operations

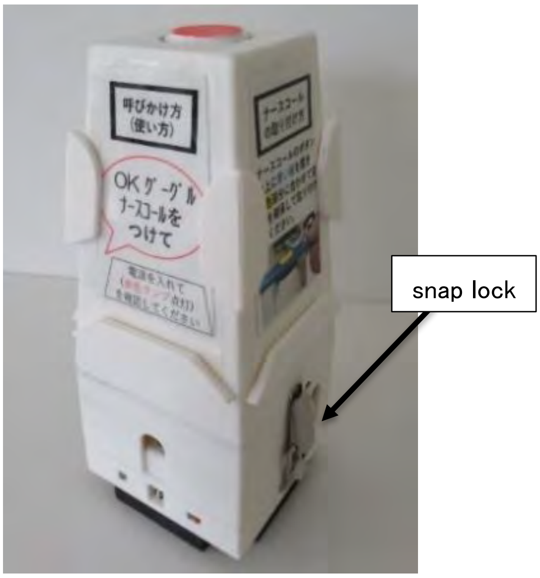
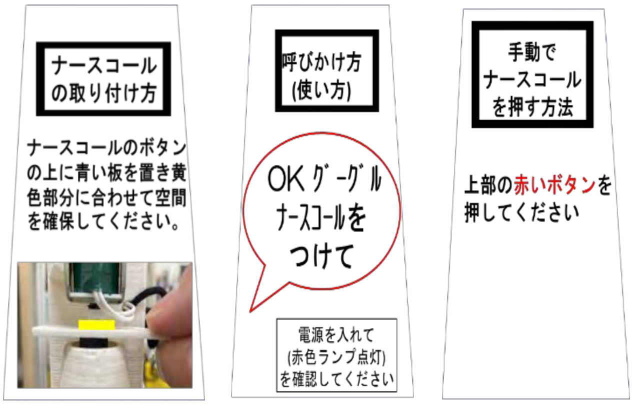


Figure 3 Appearance of development equipment

Figure 4 depicts the three cards attached to the device. Figure 4(a) illustrates the method of attaching the nurse call system, Figure 4(b) provides instructions on how to use it with voice commands, and Figure 4(c) explains the operation method for manual use. These innovations allow even patients and their families who encounter the device for the first time to easily understand how to use it.



(a) (b) (c)

(a) mounting arrangement, (b) how to call, (c) how to push
Figure 4 Display boards

Furthermore, as shown in Figure 5, in previous research cases, the device cover was fixed with four screws. In the device developed this time, as depicted in Figure 3, it is secured with a snap lock. This one-touch removal of the cover reduces the time required for nurse call setup, enabling time-saving benefits.

The installation of the nurse call button can be challenging due to the varying length of the solenoid and the distance required to activate the nurse call. Therefore, it is necessary to ensure a consistent distance during installation. To address this, we have equipped a clearance plate, as shown in Figure 6, which allows for easy installation at regular intervals. By placing this plate on the nurse call button and securing it with a clamp, it becomes easy to set up. Additionally, it is important to use specific words when addressing the AI speaker to ensure proper functionality. Therefore, we attached an explanation card to the terminal body so that even first-time users can make calls without hesitation (Fig. 4(b)).

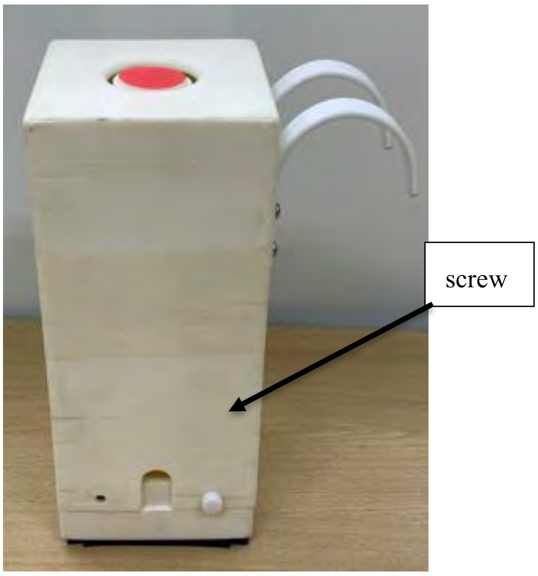


Figure 5 Equipment developed in previous research

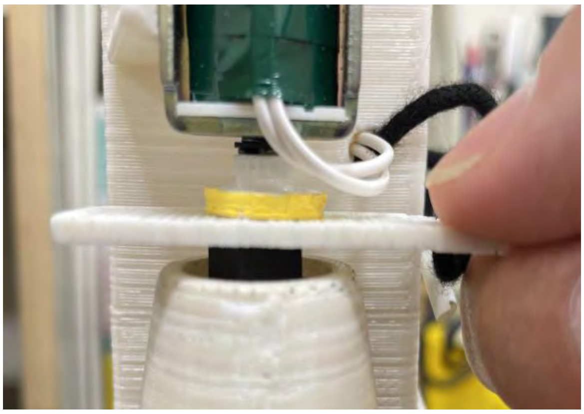


Figure 6 Spacing adjustment between solenoid and button

Effectiveness Verification

We measured and compared the installation times of the developed device and the conventional equipment that shown Fig.5. The participants for measuring the installation time of the conventional equipment were ten physical therapists, occupational therapists, and speech-language pathologists working at Matsuyama Rehabilitation Hospital.

The participants for measuring the installation time of the developed device were ten fifth-year students from National Institute of Technology, Niihama College.

This verification was conducted with the approval of the Ethics Committee at Matsuyama Hospital.

Validation Method

The verification method involved measuring the time taken to complete the following four steps:

(1) Removing the cover of the nurse call device,
(2) Adjusting and installing the nurse call at the appropriate height,
(3) Attaching the cover
(4) Speaking to the AI speaker and operating the nurse call.

After measurement, the average installation time of the two devices is calculated, and the difference between the average values is tested for significance. We also calculate the effect size for the difference.

Validation Results

The results are shown in Figure 7. The installation time in the control experiment refers to the installation time when using the conventional equipment, while the installation time in the intervention experiment refers to the installation time when using the developed device.
The average installation time for the conventional equipment was 73.4 ± 18.5 seconds, while the average installation time for the developed device was 48.2 ± 7.1 seconds, resulting in a 25.2-second improvement compared to the conventional equipment.

To examine the difference in means between the two groups, an unpaired t-test was performed, revealing a significant difference (p=0.0018).

Furthermore, we need to consider whether this is a meaningful effect size. The standardized effect size "Δ_0" is determined by equation (α), where "$\bar{x}_i$" represents the mean of the intervention group, "$\bar{x}_0$" represents the mean of the control group, "$\bar{u}_i$" represents the unbiased standard deviation of the intervention group, and "$\bar{u}_0$" represents the unbiased standard deviation of the control group.

$$\Delta_0 = \frac{|\ \bar{x}_i - \bar{x}_0\ |}{\sqrt{\frac{\bar{u}_i{}^2 + \bar{u}_0{}^2}{2}}} \qquad (\alpha)$$

The unbiased standard deviation "$\bar{u}_i$" of the intervention group was 7.1, and the unbiased standard deviation "$\bar{u}_0$" of the control group was 18.5. Substitute this into equation (α).

$$\Delta_0 = \frac{|\ \bar{x}_i - \bar{x}_0\ |}{\sqrt{\frac{\bar{u}_i{}^2 + \bar{u}_0{}^2}{2}}} = \frac{|\ 48.22 - 73.38\ |}{\sqrt{\frac{7.1^2 + 18.5^2}{2}}} \cong 1.8$$

As a result, the standardized effect size "Δ_0" was 1.8. The benchmark for standardized effect size is considered high when it exceeds 0.8, indicating a significant difference in improving the installation time (time reduction). Therefore, it can be concluded that the development of a simplified attachment-type voice nurse call device achieved the following : (1) A nurse call can be made within 50 seconds without explanation. (2) Easy to operate even for first-time users (3) Easy to install without tools.

Based on these results, it can be said that the creation of a product that satisfies the design specifications has been accomplished.

Discussion

Initially, the requested installation method from the medical institution was to attach the device to the bedside railings. However, it was found to be inconvenient in practice as the railings were frequently removed during caregiving and nursing tasks. As a result, it was decided to develop a stationary-type device, which allowed for seamless usage in caregiving without any hindrance. Additionally, during the development process of the detachable voice input device, although the functionality met the specified requirements, numerous unforeseen issues occurred. These included the number of power sources and methods for adjusting the volume, which required repeated improvements. From these experiences, it became evident that the physical realization of an idea is crucial in medical-engineering collaboration. By basing discussions on the real prototype, various hidden needs, challenges, and the addition of functionalities could be revealed.

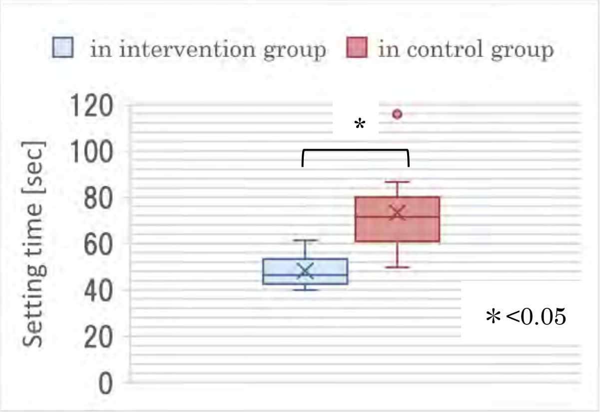


Figure 7 Comparison of installation work time

Therefore, even if the design specifications are not clear, it is important to materialize improvement ideas based on the needs of the field in order to explore hidden needs. In other words, it is crucial for us to create prototypes without spending excessive time initially.

Next, let's consider incorporating medical-engineering collaborative device development education into the curriculum, which can provide students with numerous learning opportunities. Students may feel that improvement requests from the field are endless. Additionally, it can be challenging to evaluate the efforts made by students as tangible outcomes.

Hence, providing objective evaluations based on actual usage in numerical form can alleviate project failures and mitigate the burden on students. Through continuous iterations of improvements, students can experience a sense of accomplishment.

Furthermore, during device development, when intense discussions occur between the hospital and engineering sides, the focus sometimes shifts from prioritizing usability for patients to emphasizing convenience for hospital staff. This is because in medical-engineering collaboration, users are divided into operators, patients (end-users), and purchasers (facilities/maintenance), each having different needs. Consequently, when evaluators of the developed product differ, contrasting evaluations and opinions often arise, resulting in conflicting viewpoints.

In order to create products that satisfy multiple needs and address challenges, it is necessary to first determine the minimum design specifications for each user. Products that significantly prioritize one specification often lower the satisfaction of other users. For example, there are often trade-offs between ease of installation and durability. Therefore, objective evaluation criteria that satisfy each user are crucial. These criteria serve as the goal of product development and provide students with motivation to strive towards achieving them. On the other hand, conducting experiments with patients, nurses, and other healthcare professionals in real-world settings requires numerous procedures. Obtaining objective evaluations in medical institutions necessitates following various research protocols involving human subjects, which can be time-consuming and financially costly.

However, learning these procedures is essential for engineers. It is an area that has been difficult to incorporate into traditional technical education at industrial colleges. Therefore, I believe that collaboration between medical and engineering fields is highly valuable in product development.

Conclusion

Through the implementation of an educational program focused on collaborative medical-engineering product development, we have obtained the following conclusions.

(1) It is important to materialize ideas without spending too much time, even if the design specifications are not initially clear. Creating a prototype based on these materialized ideas is crucial for exploring masked needs.

(2) The focus should be on conducting empirical experiments with the created prototypes rather than solely on the fabrication process (materializing ideas). Evaluating the effectiveness quantitatively through these experiments is essential.

(3) Close coordination between coordinators from the medical and engineering fields, as well as collaboration with healthcare staff in the clinical setting, is crucial. Setting the final goal, which includes establishing quantitative evaluation criteria, is of utmost importance.

Acknowledgments

We would like to express our deep gratitude to the Jikyo-kai Matsuyama Rehabilitation Hospital for their extensive cooperation in conducting this research.

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Current development of VPET and industry collaboration in the engineering sector in Hong Kong

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Abstract

Nowadays, Vocational and Professional Education Training (VPET) aims for the development of professional knowledge, practical skills, and personal growth for academic and career prospects. With sustainable development with the master of skilled workers in trades, a well-structured training system has developed in different countries. Some developed countries such as the United Kingdom, United States, Germany, and Singapore, have developed their training system. These trades have required practitioners to conduct mandatory training before they admit to the trades. In China, a long tradition for the mode of skills transfer from the master to protégé has developed in construction tradesmen. In Hong Kong, starting from the 1950s, a dramatic increase of skilled workers was required for industrial development. At that time, apprentices only needed to acquire basic technical skills and on-job training to fulfil basic job requirements. To enhance the training scheme in Hong Kong, the Government enacted an Apprenticeship Ordinance in 1976 to promote apprenticeship training to young people, regulate the employment of apprentices in designated trades, and supply well-trained skilled manpower for industry development. The apprentice has a job in an industry at a designated trade and studies a complementary course in Vocational Training Council (VTC) for VPET. The Office of the Director of Apprenticeship (ODA) in VTC is statutory to monitor the progress of the apprentices and promote apprenticeship training. To enhance industry collaboration, institutions in VTC such as Hong Kong Institute of Vocational Education (IVE) and Youth College (YC) have maintained very close contact with relevant industries for collaboration, schemes including Industry Attachment, Work Integrated Learning, and Workplace Learning and Assessment to current students to apply their professional skills and acquire on-job training skills and industrial development in future careers.

This paper reviews the vocational training and apprenticeship in Hong Kong, discusses the current development of the collaboration of VPET and stakeholders between the institutions, and under the apprenticeship scheme with case studies; and summarises the overall strategies in VPET which can be referenced as a model to stakeholders to enhance the recognition of the industry for future development.

Keywords: *Vocational and Professional Education Training, Apprenticeship training, Vocational Training Council, Hong Kong Institute of Vocational Education, Industry collaboration*

Introduction

The apprenticeship training system is important to ensure a continuous supply of the master of skilled workers to meet the manpower and development needs of local industries in Hong Kong. Before the 1970s, apprenticeship training was primarily available in large companies, especially in large enterprises and utility companies, with different systems and practices. These systems and their modes of operation were not subject to regulations and monitoring of the Hong Kong government other than under the Employment Ordinance, Chapter 57 (HKSAR Government, 1970). An apprenticeship training system was formally introduced in 1976 whilst the Government enacted an Apprenticeship Ordinance, Chapter 47 (HKSAR Government, 1976). This Ordinance specifies provisions governing the employment and working conditions for apprentices in specific trades, with the intent of safeguarding the interest of apprentices who are still minors at the time of the apprenticeship training.

Trends of industries in Hong Kong

Local industries in the 1970s were dominant in the manufacturing and construction sectors. The local industries in Hong Kong encountered drastic social, economic, and technological changes, including three main issues. Firstly, a lot of local manufacturing industries started moving to China and countries in South East Asia, where labour and other production costs were relatively lower; Secondly, the drastic technological changes and aspiration of Hong Kong to become a financial and service centre of the region have transformed Hong Kong into a knowledge-based economy, which require the staunch support of a workforce with higher academic qualifications, advance technological knowledge, and a higher level of professional competence (ITEA, 2000). Lastly, the development of compulsory education and rapid expansion of tertiary education in Hong Kong, resulting in students having more opportunities of attaining a higher qualification at degree and professional level. At the same time, students and their parents are no longer satisfied with jobs of a craft and technical nature and with little promise of upward mobility. Owing to the drastic changes explained above, apprenticeship training in its current form is becoming less welcomed by young people and their parents. This is also reflected from the feedback of industry stakeholders, especially in the electrical, mechanical, and construction sectors, that they are facing difficulties in recruiting an adequate number of young people to join the industries as skilled workers. Therefore, the continuous development and promotion of apprenticeship training in Hong Kong are becoming more important with a view to enhancing the effectiveness of the training and attractiveness to young people to join the sector (Pavlova, 2009).

Overview of VPET in Hong Kong

Under the existing education system in Hong Kong, few secondary students will opt for VPET at the early stage of their secondary education. About 95% of secondary students will stay in the mainstream education aiming to excel at the Hong Kong Diploma for Secondary Education (HKDSE) examination, irrespective of their learning ability, career aspiration, and personal interest. According to past statistics, about one-third of the secondary students are unable to attain the minimum requirement in HKDSE examinations to continue their studies at a degree or sub-degree level. These students switch to VPET and apprenticeship training before they join the labour market for employment. To recognise the value of VPET in Hong Kong's sustainable development, the Government set up a task force for the promotion of VPET in 2018 to consider measures necessary to support the promotion of VPET in Hong Kong (Education Bureau, 2020). The Task Force recognised that the major challenge was in changing the public's perception of VPET as an inferior choice relative to academic articulation pathways. The Task Force has made a list of recommendations focusing on the promotion and publicity of VPET as well as building an articulation ladder for VPET from secondary up to higher education level.

VPET system in other countries

Some countries in Europe, United Kingdom, United States, Germany and Singapore, they have developed their training system of the trades. These trades have required practitioners to conduct mandatory apprenticeship training before they admit to the trades. In China, a long tradition for the mode of skills transfer from the master to protégé has developed in construction tradesmen. The comprehensive and effective education and training system for producing skilled craftsmen, which has been developed from a long history of craftsmanship training tradition. The following features are found in the VPET systems from these countries:

(a) VPET forms an integral part of the national education system and is usually available at various stages of the education ladder from lower secondary level to higher education level. It is highly regarded by members of the society and welcomed by students and their parents as a means to access respectable employment;

(b) VPET usually starts after the completion of basic or compulsory education. Statistics in these countries show that a large percentage of teenagers (e.g. about two-third of students in Switzerland) will choose VPET after the lower secondary education;

(c) Dual-track mode is the most common and effective form of VPET and generally preferred by apprentices or vocational trainees;

(d) Upon completion of their training, apprentices or vocational trainees will usually be certified as skilled workers and will have acquired a qualification recognised for employment for specific trade or profession;

(e) Apprenticeship training is mostly funded by the central and local government and enterprises in the private sector. Apprentices are paid while receiving training, and are entitled to various allowances and benefits offered by the government and enterprises; and

(f) Apprentice graduates who aspire to pursue further education will have the option to continue their studies at a higher education level.

These features provide useful references for Hong Kong in the development of its VPET and apprenticeship training system (Middleton, 2009).

Current development of VPET and industry collaboration in Hong Kong

Student industrial attachment programme in the engineering sector

The student industrial attachment programme in VTC is "work-based experience programme" providing a real-life organisational context for students to develop specific or generic skills, valuable to their professional development in VPET. Students can apply and enhance their skills in reality, contribute to the organisation, and, at the same time, obtain invaluable guidance from their mentors (Vocational Training Council. 2023). All full-time IVE/HKDI Higher Diploma students are eligible to participate in this programme. In the engineering discipline, attachment students are able to provide assistance in the following areas:

(a) Conduct a survey on existing equipment/services and user needs;

(b) Draft a project plan and develop theoretical and engineering solutions to specific problems;

(c) Perform experimental or investigatory work;

(d) Build and test hardware and/or software; and

(e) Provide a cost analysis of development and/or production where appropriate.

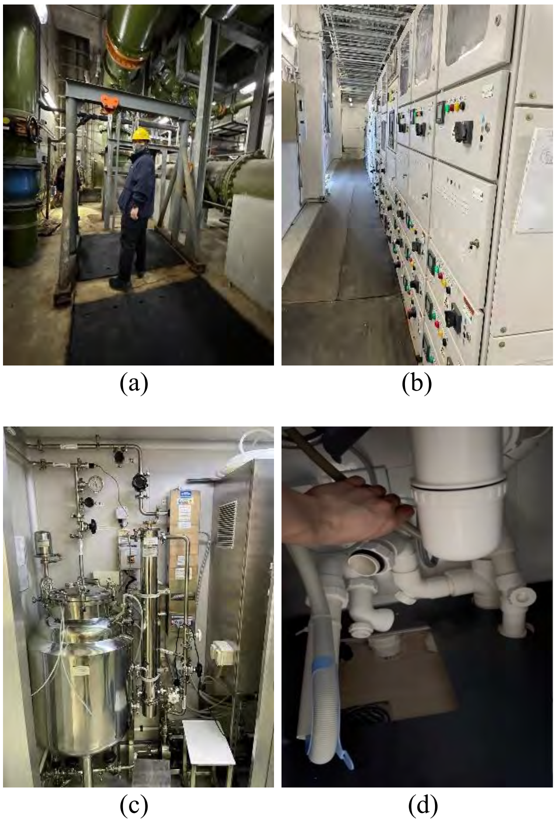


Figure 1: Examples of projects participated in the student industrial attachment programme in the engineering sector (a. sea water pump system near Victoria Harbour, b. power supply system in one of the main bridges, c. water treatment and purification system in the cosmetics industry, d. plumbing system inspection in a residential building).

During the attachment period, engineering students can strengthen their engineering skills and they could find a practical topic to conduct an Industry-Based Student Project (IBSP) during their final year of study. For example, full-time students with Higher Diploma in Building Services Engineering are attached to different companies to participate in a wide variety of projects. Figure 1 shows some examples of the projects participated in, such as the seawater pump system near Victoria Harbour, the power supply system in one of the main bridges at Kong Kong, the water treatment and purification system in the cosmetics industry, and plumbing system inspection in a residential building.

Apprenticeship training and support to industries

Apprenticeship training is one of an integral part of the VPET systems in Hong Kong and is elicited in the Apprenticeship Ordinance. A young person of 14 to 18 years of age may be employed in a designated trade (DT), only if he is employed as an apprentice under a valid contract of apprenticeship and the contract is registered with the ODA. The registration of the contract is compulsory under the Ordinance (Compulsory Registration). The Ordinance however does not require the registration of apprenticeship contracts of persons aged 19 and over in DTs. Employers however may register voluntarily such contracts with the ODA under the Ordinance (Voluntary Registration). There are 45 DTs specified by the Apprenticeship (Designation of Trades) (Consolidation) Order. All of them are in the manufacturing, construction, engineering services sectors of local industries. Trades or occupations outside the list of designated trades specified in the Order are generally referred to as non-designated trades (NDTs).

Typically, an apprentice will spend four and half days per week for on-the-job training in the workplace of his employer, and one day plus one to two evenings each week in classrooms of VTC for learning theories and technical knowledge of the related trade. The period of apprenticeship training for individual trades varies from trade to trade, ranging normally from three to four years.

In some trades, employers and apprentices generally feel that the periods of apprenticeship for their trades are too long. They have expressed that the periods of apprenticeship for their trades were determined decades ago. Technological advances in recent years have changed not only the manufacturing processes but also the mode of business transaction. The key skills of a trade to be transferred to apprentices are significantly different from those in the 1970s. With modern teaching and learning and teaching strategies being used today, apprenticeship training could be done faster and completed within a shorter period of apprenticeship. It is therefore to design a 2-year NDT to rationalise the period of apprenticeship, trade titles with job titles adopted by most employers.

ODA registers apprenticeship contracts under the Apprenticeship Ordinance for the benefits of employer and apprentice. The apprenticeship officers of the ODA conduct routine visits to ensure the training facilities of the employer are in place, and registered apprentice training is in good progress. Figure 2 shows an example of a routine visit to apprentices who are working in a commercial building in a refrigeration/air-conditioning trade. The apprenticeship officers can conciliate disputes between employer and apprentice when necessary (Office of the Director of Apprenticeship, 2023).


(a) (b)

Figure 2: A routine visit to apprentices working in a commercial building (a. on-site work, b. air-conditioning facilities).

Earn and Learn Scheme

The Earn & Learn Scheme (ELS) was implemented by VTC in 2014 with funding provided by the Government. As shown in Figure 3, the scheme includes three parties: the Hong Kong government, employers, and VTC. The Scheme is intended to attract young people to pursue vocational education and develop a career in industries or trades requiring specialised skills as well as facing labour shortage and ageing problems. The ELS is introduced to industries due to three main criteria. Firstly, the industry is facing labour shortage or/and ageing problems and it has difficulties in hiring and retaining young people. Secondly, the relevant trades are very specialised with a high level of technical content. Thirdly, the industry is committed to providing allowance and subsidy to trainees and to offer a certain salary level to trainees who have completed the apprenticeship training and are willing to join the relevant industry. Under the Scheme, an apprentice will be enrolled in a designated programme at VTC and the apprentice will sign an apprenticeship contract with an employer, and start learning practical skills at the workplace. At the same time, he will continue his study of the vocational programme on a part-time basis. During the apprenticeship training period, the apprentice will receive a salary at a guaranteed level from his employer and will receive various incentive allowances from both the employer and the Government. The salary level upon completion of the training is also guaranteed. The implementation of the ELS is considered successful in enhancing the attractiveness of apprenticeship training to young people. This can be seen from the increase in the number of apprentices from below 4,000 to around 5,000 apprentices each year since its introduction in 2014.

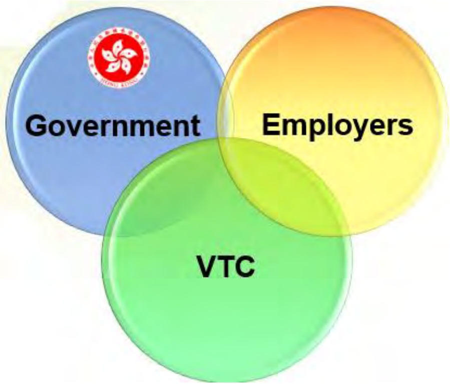


Figure 3: Three parties are involved in the ELS.

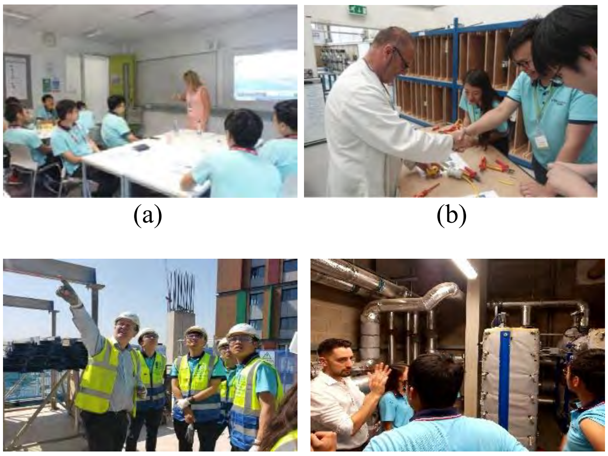
Workplace Learning and Assessment and Pilot Incentive Scheme to Employers

To further enhance the effectiveness of ELS, VTC has introduced a pilot scheme of Workplace Learning and Assessment (WLA) in 2019. The WLA mechanism is designed and developed by VTC regarding the dual-track model practised in other countries. Qualified trainers, verifiers, and assessors appointed by the employers will be engaged to conduct training and assessments of the apprentices at the workplace. The outcome of the assessment will be reported in a web-based system and monitored by the relevant academic disciplines of VTC. Professional workshops will be held by VTC for trainers and assessors on the assessment mechanism and skills. The WLA allows assessment of the apprentices' performance and competencies at the workplace at the same time and helps reduce the learning time spent by apprentices in classrooms. The above schemes are in line with the recommendation of the Task Force on the promotion of VPET which advised the Government to identify ways to facilitate better alignment between the classroom and work-based learning, to implement a dual-track learning mode. To help employers meet the additional manpower resources incurred in the WLA mechanism, the Government has introduced a Pilot Incentive Scheme to Employers (PISE) which employers will be paid an incentive allowance per apprentice after the start of assessments of the apprentices.

Student Exchange Programme for current students and International Study Programme for apprentices

To broaden the perspectives of current students, tap insights from industries abroad, and enhance professional knowledge, students had opportunities to widen their global horizons through range of outbound student exchange programmes in the United Kingdom, Australia, Japan and Singapore etc.

On the other hand, the International Study Programme was introduced in recent years to allow apprentices an opportunity to gain experience and exposure by studying short-term technical/practical courses and visiting local institutions/companies. In 2019, 14 apprentices from electrical, electronic, mechanical, construction, building Services, air-conditioning, and automobile engineering trades participated in a 2-week exposure programme in London, United Kingdom with different activities participated, shown in Figure 4.


(a) (b)

(c) (d)

Figure 4: Apprentices participated in different activities during the International Study Programme in 2019 (a. specialist lecture, b. practical workshop, c. industrial visit in a construction site under construction, d. industrial visit of a workplace with building services system).

Conclusions

The vocational training and apprenticeship in Hong Kong are embedded in the VPET system and governed by legislation that is enacted to safeguard the interest of apprentices who are still minors at the time of training. The system is monitored closely by a team of dedicated staff in VTC, who maintains close dialogues with employers and other stakeholders in industries; and staff in teaching departments in VTC, who deliver academic professional knowledge through the vocational programme to both current students and apprentices. The system is fully supported by the Government and industries, through policies and funding. To adapt to the fast pace environment and sustainable development in Hong Kong, a regular review on the training and support scheme implemented by the VTC to enhance vocational training and apprenticeship (Cribbin & Kennedy, 2002). Suggestions including increasing incentives for employers, strengthening its dual-track learning mode, enhancing its industrial collaboration and workplace learning and assessment. Such strategies can be referenced as a model to stakeholders to enhance the recognition of the industry for future development.

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PROFESSIONAL QUALIFICATIONS PATHWAYS FOR SKILLS PRACTITIONERS IN HONG KONG

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Abstract

In the review report published by the HKSAR Government's Task Force on Promotion of Vocational and Professional Education and Training (VPET) (the "Task Force") in 2020, the Task Force recommended that VPET should establish itself as a more prominent value-added pathway with the prestigious qualification it deserves, to match the perceived excellence enshrined in its academic counterpart. Professional Qualifications Pathways, like the Vocational Qualifications Pathways, should be developed for practitioners with a focus on recognised skill-based qualifications that are not underpinned by associated learning programmes. These pathways will emerge as professional routes for practitioners of the relevant industries.

In response to the recommendation made by the Task Force, the Vocational Training Council (VTC) started to undertake an initiative – *Professional Qualifications Pathway for Skills Practitioners* in 2020. This initiative aims to establish a value-borne progression pathway for in-service practitioners through a Qualifications Framework (QF) recognised skill-based qualification. In respect of this, the German Meister system offers a valuable reference for developing a Mesiter learning programme for skilled workers in Hong Kong as this system aims to equip Meister candidates with the occupational, pedagogical, and managerial competencies necessary for the chosen professions. It would also help further professionalise industry practitioners and strengthen the local VPET articulation pathway. As a start, lift and escalator engineering (LEE) was selected as the first industry where seasoned registered lift and escalator workers are provided with an opportunity to strive for the title of Meister, in the name of Skills Master or Industry Master through the Professional Diploma Meister in Lift and Escalator Engineering (PDM-LEE) programme, the first of its kind skill-based qualification at QF level 5 in Hong Kong.

This paper will focus on the tripartite collaboration between the VTC, the HKSAR Government's Electrical and Mechanical Services Department (EMSD), and The Lift and Escalator Contractors Association (LECA) in developing the PDM-LEE programme. A VPET consultancy was invited to participate in the programme development process, where an Industry Consulting Group and several Subject Matter Expert Groups were formed to identify the key roles and competencies of a Meister in the LEE industry. These findings act as valuable inputs to the curriculum design of the programme. The active involvement of industry stakeholders in the programme development apparently demonstrated strong industry-academia collaboration which could serve as a good reference for developing work-oriented PDM programmes for other trades in the future.

Keywords: *Professional Qualifications Pathway, Meister, Skills Practitioners, Industry Collaboration, VPET*

Introduction

The HKSAR Government's tracking surveys conducted in recent years reflected that a sizeable proportion of respondents still did not have adequate knowledge of the articulation opportunities available through vocational and professional education and training (VPET). Building on its work in 2015, the Task Force on Promotion on VPET (the "Task Force") was tasked to review and consider enhancements to the promotion of VPET in Hong Kong with a more targeted approach. In its review report ((VPET), January 2020) published in 2020, the Task Force's recommendation states,

> *"to explore the development of a vocational route whereby professional skill-based vocational qualifications can be acquired flexibly through an appropriate combination of vocational training at schools, workplace assessment, or in-service training, and duly recognised under the QF in close partnership with the industries".*

In this connection, the Vocational Training Council (VTC) started to undertake an initiative – *Professional*

Qualifications Pathway for Skills Practitioners in 2020. This initiative aims to establish a value-borne progression pathway for in-service practitioners through a Qualifications Framework (QF) recognised skill-based qualification.

Moreover, comprehensive studies and research have revealed a general lack of collaboration and interaction on traditional vocational education and training (VET) between institutes and industrial stakeholders (Gessler, 2017). Insufficient collaboration results in a weak relationship between school-based learning and workplace learning (Billett, 2008). The issue arises from a long-standing history of separating school-based study and employment, as well as theoretical knowledge and practical abilities. This is also reflected in the structure of VET programme as well as the curriculum of programme (Hiim, 2017).

This paper elaborates on the collaboration between the VTC, the HKSAR Government, industry stakeholders and a VPET consultancy on the development of a Professional Diploma Meister (PDM) programme, and how important the role of industry stakeholders is in curriculum design during the programme development stage so as to ensure that the VTC is grooming talent that is required by the industry.

The First Professional Diploma Meister Programme in Hong Kong

The attempt to develop unambiguous value-borne positions of VPET awards is crucial to the success of VPET. The German Meister system serves as an appropriate reference for establishing a prestigious goal for seasoned skills practitioners in Hong Kong. To achieve the title of Meister, a skilled worker must possess occupational, pedagogical, and management competencies in addition to the vocational training in his chosen trade (see Figure 1.1 below) (Philips, 1995).

Figure 1: The Competencies of a Meister

A skilled worker in the German Meister system typically receives a systematic Meister education that includes theoretical and practical trade training, business and legal training, and a Meister certificate that allows him to teach and train other apprentices. After completing the training programme, the worker may choose to take an examination leading to the title of Meister (Clément Imbert; Reynold John, 2020).

In response to the Task Force's proposal, it is recommended that the essence of this Meister system be transferred to VPET in Hong Kong to further professionalise industry practitioners and enhance the VPET articulation pathway. The Meister title, in the form of Skills Master (or Industry Master), might be used for skilled workers in Hong Kong who have achieved excellence in areas required by the associations/professional organisations of their chosen skills. The nurture of a Meister is based on a comprehensive high-level education plus years of practical experience accumulated. In terms of education, it is suggested that a more complete and currency-based VPET pathway be established by introducing the award of Professional Diploma Meister (PDM) at QF Level 5 to competent skilled workers who aspire to achieve the title of Meister. The PDM will equip candidates with the necessary skills and knowledge, in addition to the practical experience gained over their professional career development.

In Hong Kong, lift and escalator apprentices who successfully completed the recognised training (at QF Level 2) and accumulated four years of relevant work experience could acquire the status of Registered Lift Worker / Registered Escalator Worker (RLW/REW). However, after reaching this career milestone, this group of professionals will face a glass ceiling in their pursuit of professional development because there has been no further value-borne progression pathway for decades in the wake of the RLW/REW award. This phenomenon may reduce the industry's attractiveness to young people, thereby affecting the sustainable development of the industry. In other words, this profession, given its significant impact on our everyday life, deserves a more structured recognition scheme for its skilled workforce.

Thus, the VTC collaborated with the HKSAR Government's Electrical and Mechanical Services Department (EMSD) to promote the concept of establishing a Professional Qualifications Pathway for the practitioners of the lift and escalator industry. This idea is also well-received by The Lift and Escalator Contractors Association (LECA) which is the most representative lift and escalator association in Hong Kong. Such a pathway encompasses institutional education, workplace learning, and professional assessment, culminating in the accomplishment of a Professional Diploma Meister in Lift and Escalator Engineering (PDM-LEE) qualification at QF Level 5. The PDM-LEE curriculum includes industry-specific contents as well as core contents common to all conceivable professions, such as management and training know-how. The lift and escalator industry's technical terrain comprises installation, maintenance, repairing, modernisation, and dismantling, and it is supported by two pillars of professionals: Registered

Engineers (RE) and RLW/REW. In Hong Kong, there are around 6,000 RLWs/REWs and 300 REs.

Demand for the PDM-LEE Programme

The PDM-LEE programme at QF Level 5 aims to offer experienced lift and escalator workers a progression pathway for developing managerial and mentoring skills, as well as comprehensive competence in the complete spectrum of lift and escalator specialisms. A survey of registered lift and escalator workers (n = 299) was undertaken in 2021 by the VTC during the pre-programme development stage to measure the industry's demand for the programme. The survey revealed that 95% of the respondents agreed that the lift and escalator industry was important in Hong Kong (Strongly agree = 184, Agree = 100); 92% agreed that acquiring trade-specific and managerial skills in lift and escalator engineering would enhance the development of relevant industry workers (Strongly agree = 162, Agree = 113); 86% agreed that participating in this programme would advance their career (Strongly agree = 149, Agree = 109); and 82% agreed that they would participate in the programme if time allowed (Strongly agree = 131, Agree = 115).

The above results indicated that the population of current registered lift and escalator workers appreciated the potential values and benefits brought by the PDM-LEE programme. To further assess the demand for the PDM-LEE programme from prospective students, another survey of current VTC's lift and escalator students was also conducted in 2021 (n=229). The survey indicated that 90% of the respondents agreed that acquiring trade-specific and managerial skills in lift and escalator engineering would enhance the development of relevant industry workers (Strongly agree = 109, Agree = 97); 80% agreed that participating in this programme would advance their career (Strongly agree = 90, Agree = 94); and 76% agreed that they would participate in the programme if time allowed (Strongly agree = 106, Agree = 89).

According to the overall findings presented above, the registered lift and escalator workers and current lift and escalator students have demonstrated considerable support and demand for the PDM-LEE programme, which has verified the need for establishing the professional qualification pathway for them.

Engagement of Stakeholders

Employers are the key stakeholders in a skill-based and work-oriented PDM programme. Without their support and advice, it is impossible to understand the needs for manpower development in the industry. Various meetings and discussions with different industry stakeholders including LECA and EMSD were conducted to identify the needs for upskilling the current registered lift and escalator workers, and the approaches to sustain skills continuity for the industry. Besides, the VTC had appointed the Skills Consulting Group (SCG) as a consultant to assist in the development of this programme. SCG is an international work-based learning consultancy headquartered in Auckland, New Zealand. Its services comprise the entire scope of work-based learning system operations, from policy development to programme delivery. SCG creates frameworks, tools, and solutions that improve the working lives of people all around the world. SCG's main role in this programme was to facilitate the successful incorporation of work-based learning in this programme by leveraging its expertise to develop the frameworks and functional analyses of the Meister graduate; the workplace learning and assessment (WLA) strategies to achieve competence; and the competence-based standards and assessment materials to be applied in the programme.

As part of the development of the PDM-LEE programme, the VTC conducted in-depth interviews with industry partners to ascertain the need for a skilled workforce in the lift and escalator sector, determine the programme objectives, programme structure, assessment strategies and the industry's skill needs. An Industry Consulting Group (ICG) was set up to provide strategic guidance for the development of the programme. Table 1 and Table 2 spell out the terms of reference and composition of the ICG respectively.

Table 1: Terms of Reference of ICG

Terms of Reference
To advise THEi and Engineering Discipline on 1. the purpose, key roles, and functions of the Meister occupation, to inform the skills, knowledge and attributes a Meister is required to possess 2. the programme and curriculum development and quality assurance of the Professional Diploma Meister in Lift and Escalator Engineering programme 3. the learning and assessment methodologies adopted by the programme, and the distribution and prevalence of workplace learning and assessment in the programme 4. the relevance, usefulness, and currency of the programme for the Lift and Escalator Engineering Sector

Table 2: Composition of ICG

Composition
Chairman / Convenor

- Senior Assistant Executive Director, VTC

Members

- Dean, Faculty of Science and Technology, THEi (Tsing Yi), VTC
- Assistant Professor, Faculty of Science and Technology, THEi (Tsing Yi), VTC
- 2 representatives from Pro-Act Training and Development Centre (Electrical), VTC
- A representative from Workplace Learning and Assessment Project Team (Engineering Programmes), VTC
- 1 representative from Chevalier (HK) Limited
- 1 representative from Anlev Elex Elevator Limited
- 1 representative from Associated Engineers Limited
- 2 representatives from EMSD, HKSAR Government

Co-opted Members

- 2 representatives from Quality Enhancement and Accreditation Office, VTC

Consultants

- 4 representatives from Skills Consulting Group

While ICG is tasked with the strategic direction and workforce modelling of the programme, various specialised groups of lift and escalator Subject Matter Experts (SMEs) were formed for consultation upon specific industry skill requirements for the programme. Members of ICG and SMEs represent a significant proportion of the lift and escalator industry in Hong Kong. To ensure the technical accuracy and effectiveness of learning and assessment resources, SME consultation groups were utilised in the development of this programme so as to identify and determine specific curricular requirements. The SME consultation groups for this programme must be broad and include experts from installation, maintenance, testing & commissioning, modernisation, project and staff management since the Meister graduate is expected to be skilled and competent across multiple specialised areas in the lift and escalator trades. The profile of SMEs is shown in Table 3 below.

Table 3: Profile of SMEs

No	Current Position Held	Professional Qualifications	Years of Relevant Experience
1	Senior Manager	Member of HKIE and IMechE, CEng	29
2	Technical Manager	Registered Lift and Escalator Worker	18
3	Maintenance Manager	Registered Lift and Escalator Worker	23
4	Senior District Manager	Member of IPlantE, CEng	24
5	Field Manager	Member of HKIE, Fellow member of IMechE, CEng, RPE, REA	20
6	Supervising Engineer	RPE, CEng	40
7	Senior Project Manager	Registered Lift & Escalator Engineer	38
8	Manager	Registered Lift & Escalator Engineer	10
9	Senior Compliance Manager	Registered Lift & Escalator Engineer	34
10	Manager (Overhaul)	Registered Lift Engineer	7
11	Senior Manager, Technical Dept.	Member of IMechE, CEng, Registered Lift & Escalator Engineer	28

Structuring the Programme Curriculum in Collaboration with the Industry

A functional map of the Meister role was developed in collaboration with the ICG in the course of researching the requirements of this role. This analysis was used to justify the design of the programme, its curriculum, and the workplace learning and assessment requirements. The programme offers the conceptual frameworks and tools that these skilled workers need to engage meaningfully in the Meister position as outlined in the functional map, in which the key purpose of the Meister role and its four key roles (KRs) are described in Table 4 below. After defining the KRs, the ICG also identified various levels of functions for each key role separately and map it with the relevant unit standards, which were used to define the scope and level of assessment required in the programme. These unit standards were further elaborated through consultations with respective SME groups who were experts in their specialist fields as mentioned above so as to specify the knowledge, skills and attributes (the outcomes), and the minimum standard a candidate must meet to demonstrate the achievement of the outcomes. They contribute to ensure that learning, teaching and assessment are relevant to the role of a Meister.

Table 4: Key Roles of Meister

Key Purpose:

Plan, organise and manage the installation, modernisation, examination, and maintenance of safe, reliable and high quality lift and escalator services; through the development of capability and professionalism, and the leadership, of personnel and operations.
Key Roles of Meister:
1. Optimise performance of equipment and operations through innovative use of technology. 2. Manage staff to carry out complex installation, modernisation, examination and maintenance activities for lifts and escalators. 3. Plan and manage installation, modernisation, examination, and maintenance projects and tasks. 4. Develop the capability of self and staff.

The POs (Table 5) are derived from the KRs listed in Table 4 and they state what is expected of graduates after completing the programme. To ensure graduates are competent across all POs and KRs, the PLOs (Table 6) were developed to specify the competences graduates will be able to acquire upon completion of the programme. The PLOs are a summary of the knowledge and skills that students will learn. All PLOs are developed to meet the POs and to facilitate assessment of the programme contents and activities by the teachers. These PLOs specifically define the competencies, skills / know-how, and knowledge required by the graduates to fulfil the KRs or functions of the Function Map. In fact, the skills / abilities demonstrated by students in measurable ways at the exit point of the programme reflect the degree to which the POs have been fulfilled. With the well-defined POs and PLOs, the curriculum is structured and translated into a number of modules which represent the core elements in the curriculum, providing the necessary professional knowledge, skills and abilities required by the expanding lift and escalator industry, and nurturing students as technical heads / technical managers / superintendents, sitting at the apex of the technical leadership hierarchy below the role of lead project or design engineer.

Table 5: The Programme Objectives (POs) of PDM-LEE

Programme Objectives (POs)
1. To develop practitioners into a Meister of the industry who possesses and renders professional, managerial, and mentoring competencies in their work. 2. To expand and develop practitioners' technical expertise in masterminding the conduct of a range of types and scales of lift and escalator engineering projects from a technical perspective. 3. To equip practitioners with the tools and methodologies to critically evaluate and improve the quality, efficiency, and cost effectiveness of lift and escalator engineering projects, ensuring their financial viability and statutory compliance. 4. To equip practitioners with solid knowledge of mentoring and coaching so as to prepare them for taking up a training role to facilitate the continuity of skills excellence in the industry. 5. To develop practitioners' awareness of technological and operational innovations and their impact on the development of the trade.

Table 6: The Programme Learning Outcomes (PLOs) of PDM-LEE

Programme Objectives (POs)
1. Critically evaluate and deploy the technical competencies required in lift and escalator engineering projects. 2. Manage staff and projects to execute lift and escalator works and operations of various types and scales with consideration of costing and legal compliance. 3. Plan, design, and conduct the training and development activities of lift and escalator engineering supervisors and technicians. 4. Keep abreast of new technology related to the lift and escalator industry, and examine the feasibility of its applications to the industry. 5. Demonstrate the possession of a comprehensive set of excellence and commit with professional ethics as required in fulfilment of the title of Lift and Escalator Meister.

Conclusions and the Way Forward

This paper introduces the development of a professional qualification pathway for the skills practitioners in the lift and escalator industry through the newly launched PDM-LEE programme at QF Level 5, which features the tripartite collaboration between the VTC, the HKSAR Government and the industry in the development of the programme, including the key purpose and key roles of a Meister, programme objectives, and programme learning outcomes of the programme. In particular, the incorporation of the current industry practice and assessment of competences in this value-borne programme largely attributes to the contribution of the ICG and SMEs.

The PDM-LEE programme, being the first of its kind skill-based qualification at QF Level 5 in Hong Kong seeks to develop Lift and Escalator Meister by providing high-quality advanced education and training in lift and escalator engineering. It is undoubtedly a significant milestone in the development of VPET in the territory. As a long-term endeavour of establishing a complete VPET progression pathway, the articulation opportunity beyond QF level 5 is yet to be explored.

Grounded in the successful launch of the PDM-LEE programme and the valuable experience gained, the VTC will be rolling out the second PDM programme for the power electrical engineering industry in the latter half of 2023 to meet the manpower development needs of the industry. Meanwhile, the demand for a PDM programme in the sectors of gas engineering, air-conditioning and refrigeration engineering and automotive engineering is being measured so as to nurture more skills masters, benefit more industries and ultimately contribute to the economic growth and prosperity of the Hong Kong in the long run.

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Posters

ISATE 2023
Submission ID
K3DZ9M
Session type
Poster
+ Poster Session
Track
Teaching & Learning

Bio-Maister: Free online virtual learning system for engineering experimental training

技術実験学習用の無料のオンライン仮想学習システム：バイオマスター

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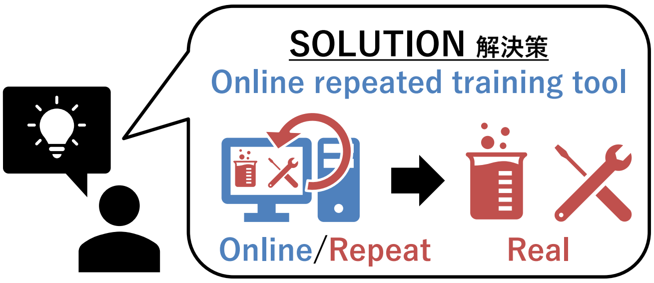
Miho Furue: Cell mimic,

Summary



Background: The exercise with hands-on training are indispensable for engineering education. However, **training course includes time, costs and safety issues.**

工学教育には手を動かす実習が欠かせませんが、**時間・コスト・安全性の問題**があります。

Results: We developed an **online virtual learning system named Bio Meister and PCR experiment content** to run on it. We used it in an actual class of 60 students and received high grades from the students.

私たちは**オンライン仮想学習システム「バイオマイスター」とその上で動作するPCR実験コンテンツを開発**し、実際に60人の生徒のクラスで実施し、生徒から高い評価を得ました。

Conclusion: Our remote tool is most effective for **repeated rehearsal before real training.** Developing a remote device that allows everyone to learn advanced techniques safely contributes to engineering education.

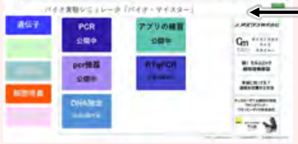
このリモート ツールは、**実地トレーニング前の繰り返しリハーサル**に最も効果的です。 高度な技術を誰もが安全に学べる遠隔装置の開発は、工学教育に貢献します。

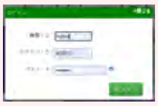
1) Features 特徴

1) Online
2) Multi organizations
3) Multi users (>100 users/organization)
4) Multi contents
5) Free
6) On way (no branch)
7) Time attack (evaluate only by “time”)

2) Overview 概要

Front page



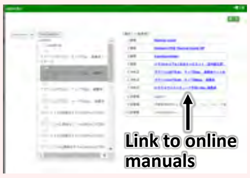


Login

Experiment page

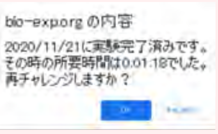
Detailed step
Choices
Input

Choose tools & materials



Link to online manuals

End (Time)

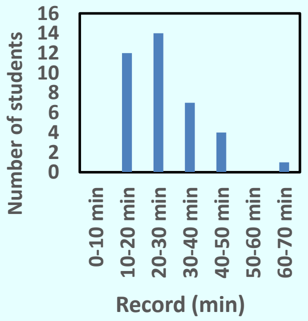


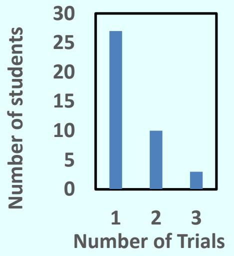
bio-exp.org の内容
2020/11/21に実験完了済みです。
その時の所要時間は0.01.18でした。
再チャレンジしますか？

Control window

[redacted]

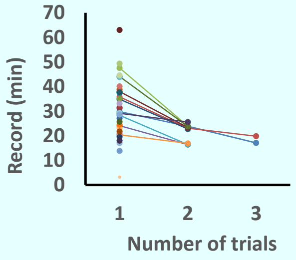
3) Result of class 2023 結果





The more trials the better records

繰り返えすと、成績アップ



4) Voice of students 学生の声

Voice of 58 students in bioengineering course in 1st semester of 2020.

Good

- I was impressed that **almost the same operation was reproduced** (ほぼ同じ操作が再現)in this app.
- Performing PCR operations on a PC is fresh, and it is a good **app for checking the operation**(操作の確認に良い).
- Although **I couldn‘t learn experiments by just watching videos**(ビデオ見では学べない), I got an **effect close to actually operating**(実際の操作に近い) PCR by using this app.

Fair

- I **wanted to try a real experiment next**(実際の実験がしたい).
- I felt the procedure of the pseudo-experiment operation was **somewhat complicated** (やや煩雑).

Poor

- It was difficult to understand PCR operation because I was **conscious of the operation and bugs** (操作とバグが気になり) of the application.
- Since **I wasn‘t used to online experiments** (オンライン実験に慣れてなく), it was tough.

Practical report of cross-cultural online communication between Thai and Japanese colleges of technology: from the point of view of coordinating communication of supporter students

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Objective

This presentation highlights how participants from Thailand and Japan coordinated their communication during an online conversation session to achieve mutual understanding. Furthermore, we argue that this practice will contribute to the development of tutors who will support international students.

Background

The first Kosen in Thailand was established in 2019 and a transfer program to Japanese national colleges of technology began in 2021. This practical report is about the specific support and pre-education for Japanese language competency for these students before coming to Japan.

In the field of language education, since the beginning of the 2020s, due to Covid-19, educational practices incorporating telecollaborative exchanges (Thorne, 2016) have attracted more attention. However, in online communication, this knowledge has been little accumulated.

➢ Research Question

How do participants, who faced differences in language proficiency levels and cultural backgrounds, coordinate their communication in the online environment?

Methods

Online exchange “Nihongo Hiroba” by Zoom

➢ Goal of practice

Students get used to using Japanese language while having fun through sessions.

➢ The aim of activities

The aim is to allow participants to coordinate their communication, including the use of English or other online tools such as chat and screen sharing.

➢ What does coordinating communication mean?

It is attempts made by participants who faced differences in language proficiency levels or cultural backgrounds to establish mutual understanding.

Flow of each session (30min):
①Instruction and demonstration5min
②Group work　20min
③Reflection　5min

だれもいない島に1か月行きます。
3つだけ物を持っていくことができます。
何を持っていきますか？どうしてですか？

You will go to an island which nobody lives for 1 month.
If you can bring 3 things to the island, what will you choose?, why?

今日のトピック/Today's topic

・お菓子（sweets/snacks）

①あなたの国では、どんなお菓子が人気ですか？
What kind of sweets/snacks are popular in your country?
②伝統的なお菓子はありますか？
What kind of traditional sweets does your country have?

Figure 1. Slides for class

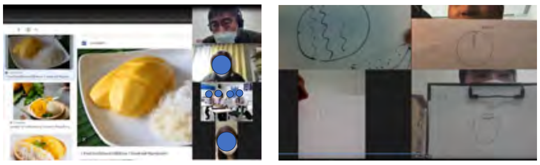
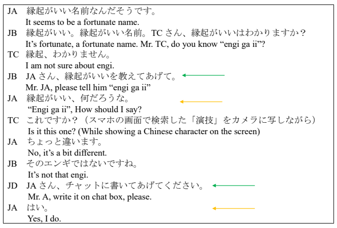


Figure 2. During class

Results

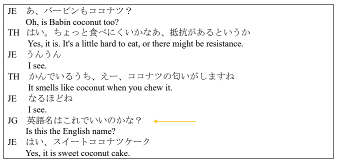
Coordinating communication：

Case 1.



JA　縁起がいい名前なんだそうです。
It seems to be a fortunate name.
JB　縁起がいい。縁起がいい名前。TC さん、縁起がいいはわかりますか？
It’s fortunate, a fortunate name. Mr. TC, do you know “engi ga ii”?
TC　縁起、わかりません。
I am not sure about engi.
JB　JA さん、縁起がいいを教えてあげて。
Mr. JA, please tell him “engi ga ii”
JA　縁起がいい、何だろうな。
“Engi ga ii”, How should I say?
TC　これですか？（スマホの画面で検索した「演技」をカメラに写しながら）
Is it this one? (While showing a Chinese character on the screen)
JA　ちょっと違います。
No, it’s a bit different.
JB　そのエンギではないですね。
It’s not that engi.
JD　JA さん、チャットに書いてあげてください。
Mr. A, write it on chat box, please.
JA　はい。
Yes, I do.

Case 2.



JE　あ、バービンもココナツ？
Oh, is Babin coconut too?
TH　はい。ちょっと食べにくいかなあ、抵抗があるというか
Yes, it is. It's a little hard to eat, or there might be resistance.
JE　うんうん
I see.
TH　かんでいるうち、えー、ココナツの匂いがしますね
It smells like coconut when you chew it.
JE　なるほどね
I see.
JG　英語名はこれでいいのかな？
Is this the English name?
JE　はい、スイートココナツケーク
Yes, it is sweet coconut cake.

Q:How was “Nihongo Hiroba”?

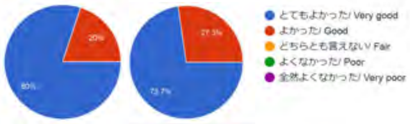


Figure 3. Survey results (Left: Thai side, Right: Japan side)

＜Comments＞

- We were able to continue talking without fear when we both encountered difficulties and couldn't comprehend a particular word.
- I was able to learn a lot by exchanging cultures and foods that I learned for the first time.
- I had a lot of fun talking and the Thai students actively tried to talk to me.
- Time was short.
- I think it would be better to make a system that allows Thai students to speak more.

After starting the practice (Case 1), like JA, students are trying to coordinate their communication by being prompted by teachers (JB or JD), but as time passes (Case 2), like JG, students are doing it on their own initiative.

Discussion

1. On both sides, more than 80% of the participants answered that the practice was “good”.
2. Participants commented that they realized the need to coordinate their communication when speaking with foreigners.
3. It has been suggested that this practice helps students improve their skills in connecting with individuals from various linguistic and cultural backgrounds.

Acknowledgment: This work was supported by JSPS KAKENHI Grant Number JP18K12417.

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SUPPORTING EMPLOYEE LEARNING THROUGH EFFECTIVE WORKPLACE LEARNING SYSTEMS AND PRACTICES: LESSONS FROM SINGAPORE

Belinda Ng, Azizah Mohd and Martin Lee

National Centre of Excellence for Workplace Learning, Nanyang Polytechnic, Singapore

ABSTRACT

Employees today must engage in continuous learning to adapt to frequent job and skills changes. Increasingly, organisations are embracing workplace learning as a means to equip their employees with competencies to take on new work.

For effective learning to occur, it is essential to establish a work setting that is conducive to the acquisition and application of knowledge and skills. This is where employers play a crucial role, through interventions such as implementing effective policies, systems and processes. This study examines the systems and practices put in place by Singapore employers to establish a work setting that fosters employee learning, and its impact on learning outcomes.

INTRODUCTION

Workplace learning is an effective form of learning as it enables the employee to establish connections between new and pre-existing knowledge, allowing for better understanding within the relevant context and improved retention and skills utilisation (Marsick & Watkins, 1999).

For learning to be effective in the workplace, the conditions within the workplace must be supportive of employee development (Billett, 2004). Employees in workplaces that are supportive tend to apply learned skills more readily on the job. On the contrary, an unsupportive work environment was identified as the greatest inhibitor to skills utilisation (Gilpin-Jackson and Bushe, 2007). Organisations can create supportive learning conditions by means of policies, systems and practices (Marsick & Watkins, 1990).

The National Centre of Excellence for Workplace Learning (NACE), set up in 2018 by SkillsFuture Singapore and Nanyang Polytechnic, developed the National Workplace Learning Framework ("Framework") to serve as a holistic guide for organisations to create conditions at the workplace that foster employee learning. This presentation highlights exemplary workplace learning systems and practices aligned to the Framework which organisations can adopt to cultivate a conducive work setting that nurtures employee learning.

THE NATIONAL WORKPLACE LEARNING FRAMEWORK[1]

Six components of the Framework to guide the establishment of a work setting that fosters learning.

Strategy: Develop strategic learning and development initiatives that support business goals.

Leadership: Cultivate leadership practices that foster a learning-friendly culture.

Planning: Arrange workplace learning activities systematically and purposefully.

Training Needs Analysis: Consider the needs, costs, benefits and suitability of learning solutions.

Environment: Establish a positive learning environment that caters to the diverse needs of learners at the workplace.

Implementation and Processes: Implement a variety of workplace learning solutions, evaluate learning outcomes and continuously improve on plans and interventions.

Organisations that have exhibited a discernible workplace learning culture through the implementation of policies, processes, and practices aligned to the six components of the Framework can be recognised under the National Workplace Learning Certification.

[1]Copyrights by NACE led by NYP

METHODS

Qualitative: On-site observations of workplace learning practices and interviews were conducted with over 200 individuals, including senior leaders, line managers and employees from nine organisations recognised under the National Workplace Learning Certification.

Quantitative: A questionnaire was administered to 397 employees three months after they had completed a Continuing Education and Training course in Singapore to collect data on skills utilisation and four workplace learning practices aligned to the Framework. The study analysed the correlation between skills utilisation and the four measured parameters. A 7-point Likert scale was used, with 1 indicating the lowest level of agreement and 7, the highest level of agreement.

QUALITATIVE FINDINGS

Employees found learning to be effective with the following workplace learning practices in place:

1. Promoting learning and knowledge sharing through platforms such as such newsletters, learning festivals, hackathons and communities of practice.
2. Leaders taking on the roles of being role models for continuous learning and mentors to guide employee development.
3. Acknowledging the learning efforts of employees through rewards and recognition.
4. Identifying employees' interests and learning gaps periodically or when new competencies are required based on the growth plans of the organisation.
5. Empowering managers to coach employees to help them in acquiring and applying new knowledge and skills.
6. Providing the opportunities and resources, such as equipment, tools and time, to apply acquired skills in performing work tasks.
7. Deploying a variety of workplace learning solutions across a range of platforms to suit the diversity of learners.

Holistically these activities foster a strong workplace learning culture over time.

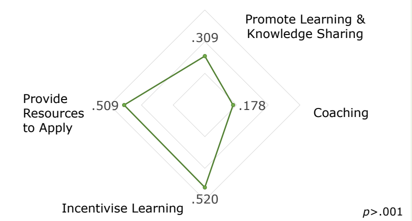
QUANTITATIVE FINDINGS

The data revealed that:

1. Employees reported moderate skills utilisation and some supportive workplace learning practices within their organisations. However, a notable majority disagreed that they have been incentivised for applying newly acquired skills.
2. Significant positive correlations exist between supportive workplace conditions and skills utilisation, suggesting that employees at workplaces with effective learning systems and practices are more likely to apply acquired skills to their jobs.

Parameters	M	SD
Skills Utilisation	4.80	1.27
Promote Learning & Knowledge Sharing	4.85	1.17
Coaching	4.81	1.32
Incentivise Learning	3.14	1.46
Provide Resources to Apply	4.53	1.56

Correlation with Skills Utilisation



CONCLUSION

This study highlights the significance of conducive work settings in facilitating employee learning. While there are organisations with good workplace learning practices, there are others that would benefit from improvements. The Framework guides organisations to develop effective systems and practices to promote continuous learning and enhance outcomes. Organisations seeking to equip their workforce with competencies may wish to consider adopting the practices implemented by exemplary organisations certified under the Framework.

Acknowledgements: The quantitative study is supported by the SkillsFuture Singapore's Workforce Development Applied Research Fund (GA19-01).

THE EXPERIENCE IN TEACHING AND LEARNING THROUGH DEVELOPING AN AI PHARMACIST IN HONG KONG

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Introduction

- Healthcare professionals, including pharmacists, are scarce and are not readily available all the time for consultation, especially during lockdowns where public members are restricted from going out.
- To help tackle this, a group of students and teachers developed an artificial intelligence (AI) pharmacist.
- The rapid development of artificial intelligence has the potential to revolutionize the healthcare industry. [1]
- This study aims to explore the teaching and learning experience of students engaged in developing an AI pharmacist.

Method

- A lecturer guided six students to develop an AI Pharmacist app.
- Students were responsible for researching drug information and relevant health advice and disease information.
- Information generated by the students would be reviewed by the lecturer for accuracy.
- The data was incorporated into the AI Pharmacist and an IT specialist assisted in the development of the app.
- Active learning was encouraged through research, group discussions, and project-based learning. This approach could enhance students' critical thinking, problem-solving, and collaboration skills.

Live demonstration of the A.I. Pharmacist app showcased on an interactive display.

Empowering healthcare: The A.I. Pharmacist app provides insightful responses to an audio inquiry regarding persistent fever.

Students presenting their developed AI pharmacist app.

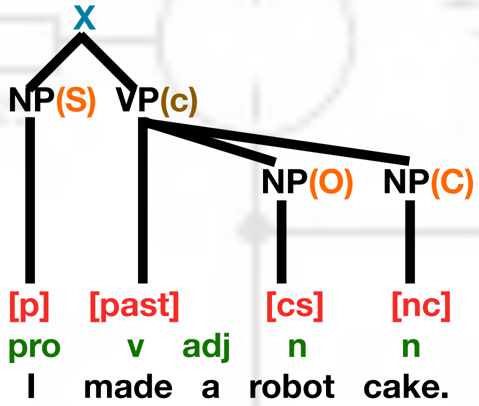
Discussion

- The development of an AI pharmacist requires a combination of computer science and healthcare knowledge, including an understanding of healthcare systems, the role of pharmacists in patient care, knowledge of drug interactions, pharmacokinetics, and disease states.
- The development of AI pharmacists poses several challenges for students. One of the main challenges is the integration of technical and healthcare knowledge. Students may come from either a technical or healthcare background, and bridging the gap between these two fields can be difficult.
- Another challenge is the rapidly evolving nature of AI technology means that students must be able to adapt quickly to new developments in the field.
- Further challenge is the ethical considerations involved. Students must be able to navigate complex ethical issues, such as data privacy and bias. This requires a deep understanding of the ethical principles involved in healthcare and technology.
- The development of an AI pharmacist presents a unique teaching and learning experience for students, characterized by its interdisciplinary nature and real-world applicability.
- Our experience suggest that students engaged in this project were able to develop valuable skills in AI, pharmacy, ethics, and teamwork, while also navigating the challenges inherent in such a complex undertaking.
- To further enhance the learning experience, educators could consider providing additional resources to help students bridge the gaps between disciplines, such as workshops on domain-specific knowledge or interdisciplinary communication strategies.
- Additionally, incorporating ethical considerations throughout the project can help students develop a deeper understanding of the ethical implications of AI in healthcare.

Conclusion

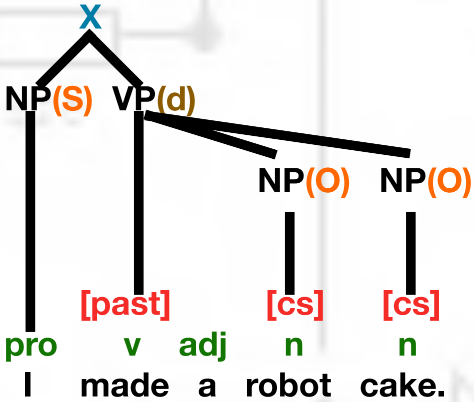
- The teaching and learning experience of students developing an AI pharmacist offers valuable insights into the potential benefits and challenges of interdisciplinary, real-world AI projects. Ultimately contributing to the ongoing discourse surrounding the integration of artificial intelligence in healthcare settings.
- By fostering collaboration and skill development across disciplines, these projects can help prepare students for the rapidly evolving landscape of healthcare and beyond.

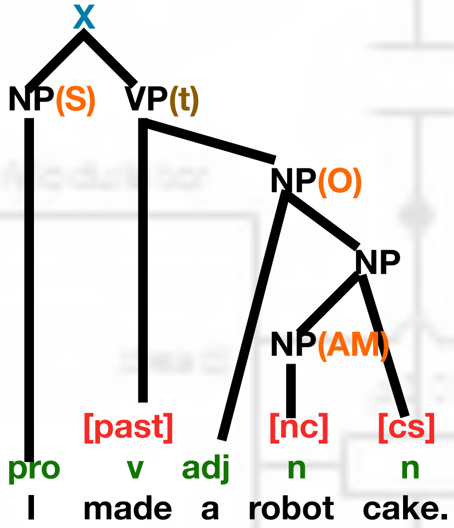
Reference:
1. Kocakoç, İ.D. (2022). The Role of Artificial Intelligence in Health Care. In: Bozkuş Kahyaoğlu, S. (eds) The Impact of Artificial Intelligence on Governance, Economics and Finance, Volume 2. Accounting, Finance, Sustainability, Governance & Fraud: Theory and Application. Springer, Singapore. https://doi.org/10.1007/978-981-16-8997-0_11



An ambiguous sentence admits of two or more possible interpretations. This can either be the result of an ambiguous word or an ambiguous structure. The sentence, ***I made a robot cake***, has ambiguous structure. What are the three possible meanings? Diagramming can help students parse these possible meanings and think about rephrasing.

This unique diagramming system is based loosely on Chomsky's X-Bar Theory but it not dependent on it. The technique aims to help students learn how to identify, chunk, and relate the parts of a sentence to better understand meaning and develop better grammatical skills.





This sentence diagramming technique is still a work in progress. A textbook using the technique is in development. This poster is a way to get constructive feedback and improve the text. We welcome your comments.

Using Sentence Diagramming to Understand Multiple Meanings of Ambiguous Sentences

The system involves identifying *parts of speech, phrases, clauses, functions, details, predicate patterns* and making connections between them. Doing this, raises grammatical consciousness and provides a scaffold from which to teach students IN the target language. This visual technique appeals to many engineers and lends itself well to teaching in the target language to students largely educated via the grammar translation technique.

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TECHNOLOGICAL AND ENGINEERING LITERACY IN SOPHIE PROJECT: NOVEL TEACHING IDEAS

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Abstract

Education in technological and engineering literacy has never been more necessary for students to face future challenges. This trend drives the college to equip students with a broad conceptual understanding of technology and its place in society, transforming them into technological and engineering literate, who are expected as active participants in the technological world, careful creators and users of technology, to meet the requirements of the future employment market. The present paper studied the effectiveness and effect of delivering technological and engineering literacy to students by participating in the 'SOPHIE' project – a tertiary engineering students project in which multi-disciplinary students from different backgrounds, work as a team to design, engineer, and build solar-powered electric vehicles to take part in the world's biggest and most prestigious solar car competition, The Bridgestone World Solar Challenge (WSC). With the era of Education 4.0, students involved in the project practice their organizational, collaborative, and project management skills through the hands-on real-world experience of creating a solar car among energy, automotive, engineering, material sciences, and IT sectors.

This research examined, analysed and evaluated the indirect measurement data collected from the Evaluation of Student's Performance (ESP), and the Survey of Employer's Views on the graduated student participants (API) conducted by the 'SOPHIE' project mentors. It also revealed that the technological and engineering literacy of the students, who participated in the 'SOPHIE' solar car project, was significantly enhanced in terms of knowledge and techniques application, problem identification and solving, time and quality commitment, communication and collaboration, self-directed continuing professional development, and professional and ethical responsibilities. Students' participation in the SOPHIE solar car project enables them to practice technological and engineering literacy; this experience aided them to adapt well to the workplace in the future and to apply their engineering knowledge, techniques, and skills to develop future technologies.

Introduction

The research examined the effectiveness and effect of delivering technological and engineering literacy using the indirect measurement data collected from ESP among 51 participants in the solar car project at IVE from the Academic Year 2018 – 2019 (AY18/19) to the Academic Year 2021 – 2022 (AY21/22). It also studied the influence on the working performance using the indirect measurement data, the API calculated from the Survey of Employer's Views, among the 29 graduates who were involved in the VTC solar car project during the period. Data in ESP and API were set up according to the Graduate Attributes (GAs) from the Hong Kong Institution of Engineers (HKIE), the professional body of engineers in Hong Kong.

Capstone Engineering Project and Project-based Learning

The Vocational Training Council (VTC) solar car project is one of the flagship projects under the Industrial Attachment & Industrial-Based Student Project (IA-IBSP) Scheme of the Engineering Discipline, Hong Kong Institute of Vocational Education (IVE). The scheme is a work-based experience scheme provided by the IVE Engineering Discipline for its final-year students. It usually takes place during the final semester of the students to let them work related to a project in the field of engineering for developing their specific or generic skills in reality and adding value to their professional development.

Regarding the purpose of the IA-IBSP scheme, it allows students to integrate and apply the knowledge they have learnt from their study, and to identify and learn new knowledge required for working in the project. It helps develop students' social connections between learning communities (student-to-student and student-to-discipline), shape students' identities as future engineers, and enhance student retention.

With the project-based learning approach of a capstone engineering project, VTC solar car project exposes student participants to a series of practical tools and methods, assisting them in constructing new knowledge, understanding and skills when building a new solar car. The construction of a solar car and the WSC included in the VTC solar car project make it works like a capstone engineering project that incorporates real-life challenges that focus on authentic problems or questions whose solutions are potentially implemented.

Technological and Engineering Literacy

Hoepfl (2020) defined that literacy in any field represents knowledge and/or competence in a specific area. The literacy that this paper focuses on is literacy in technology and literacy in engineering. Technological literacy is the ability to use, manage, evaluate, and understand technology. It focuses more on the products or outcomes of the engineering process and the relationship between technology and society, while engineering literacy focuses more on understanding the process of creating or designing technological artefacts or systems. Since technological literacy and engineering literacy are only slightly different and they are extremely closely related, the wording 'technological and engineering literacy' is used to refer to the capacity to use, understand, and evaluate technology and to understand technological principles and strategies which are required for solution development and goal achievement.

The present paper studied the performance enhancement of the student participants in terms of the following aspects drawn in National Assessment Governing Board (2018):

· Knowledge and techniques application
· Problem identification and solving
· Time and quality commitment
· Communication and collaboration
· Self-directed continuing professional development
· Professional and ethical responsibilities

Target Student Group

The VTC solar car project is operated by teaching staff and a group of students in the final year of their High Diploma program in the IVE Engineering Discipline. The project was established in 2009 with the aim of supporting the initiatives of green transportation by building its self-developed solar car, SOPHIE. After several generations of evolution, the solar car team has developed its solar-powered electric vehicles ranging from SOPHIE I to SOPHIE VI, SOPHIE 6s and SOPHIE 8 and has obtained many remarkable achievements in the international arena. To further demonstrate the possibility of green transportation and enable students to gain experience in international competition, the team has started connecting with WSC, the world's leading solar car competition held in Australia every two years, since 2013 with its SOPHIE IV.

Through the race, teams are challenged to design, engineer, and build their own solar-powered electric vehicle according to the event regulations and enter their car into one of the three classes, including challenger class, cruiser class, and adventure class, to race over 3000km across the Australian outback from Darwin in Northern Territory to Adelaide in South Australia within six days. Therefore, the VTC solar car project sets every two years as the project cycle for the team to develop a new solar-powered electric vehicle and participate in the WSC.

Figure 1 - SOPHIE IV in Adventure Calss of WSC 2013

Figure 2 – SOPHIE V in Cruiser Class of WSC 2015

Figure 3 – SOPHIE VI in Cruiser Class of WSC 2017

Figure 4 – SOPHIE 6s in Cruiser Class of WSC 2019

From the preparation and construction of the solar car to the race in WSC, the student participants face different challenges, such as interdisciplinary knowledge, hands-on science and engineering skills, self-directed learning and innovative thinking. This helps develop students' collaboration, management and innovation abilities and prepares them for unknown future careers and increasingly complex professional environments. With the rapid growth of the students in the engineering culture through their participation, the project always starts as a challenge for students and ends as a task for scientists and engineers better prepared by their nature.

Since the solar car project is the IA-IBSP of the final year students in IVE Engineering Discipline, students play lead roles in the project to develop the new SOPHIE. At the same time, the teaching staff acts as the project management team and their project mentors, providing advice and administrative support to students and the project and ensuring that the project remains on track.

Students typically participate in the solar car project for one year, as student helpers for the first half of the year, and as team members for the second half. If students have an outstanding performance during their participation, they may also be invited to be the advisors after graduation from their Higher Diploma program to provide students with technical support and experience sharing. This practice ensures that design knowledge, hands-on skills, and experience can transfer from year to year and to enable SOPHIE to progress over the years.

After participating in the WSC, the shortcomings of SOPHIE and the worth learning technologies from competitors are summarised to define the improved technical specifications and add-on features for building a better performing SOPHIE compared to the past generations.

The SOPHIE project team includes 10 to 20 student members from four Higher Diploma programs, namely the Higher Diploma in Electrical Engineering (HDEE), Mechanical Engineering (HDME), Automotive Engineering (HDAE), and Aircraft Maintenance Engineering (HDAME), every academic year. They are mainly divided into two groups, the electrical team and the mechanical team, according to their majors and interests. The electrical team is responsible for electrical systems, including the solar panels, battery pack, motors and controllers, wiring, and other accessories such as dashboards, headlights, etc. The mechanical team is responsible for the mechanical systems, including the car's aerodynamic design, carbon fibre body shell, suspension system, and other accessories like car seats, windshields, etc.

The overall project is overseen by a management team of 5 teaching staff. The management team helps coordination, administration, procurement, publicity and promotion work, and contacting industry partners, and sponsorship. It also grades and advises students' performance in the project and ensures the development of the new SOPHIE is on track to participate in the coming WSC.

The project follows a tight schedule during its project cycle, which begins in December and ends two years later in November when the WSC is completed. Improvements on the car design, specifications and features are mainly conducted in the first half year of the project cycle, and the procurement of components and construction of the car are carried out in the following one year. The vehicle must be completed and ready for testing by early May of the final year, and it is then shipped to Australia to race by the end of August. The last month of the project cycle is for reviewing the team performance in the WSC and summarizing the shortcomings of SOPHIE and the worth learning technologies from competitors.

Conclusions and Discussions

With the examination, analysis and evaluation of the indirect measurement data collected in ESP and API, it is found that the technological and engineering literacy of the students and graduates, who participated in the VTC solar car project, was significantly enhanced in terms of knowledge and techniques application, problem identification and solving, time and quality commitment, communication and collaboration, self-directed continuing professional development, and professional and ethical responsibilities.

Besides, regarding the feedback from the project mentors and the remarks on the API from the employers, both the students participants and the employers had positive reflections to the VTC solar car projects. Some of their comments towards the project are listed below as a reference.

Some Comments from Student Participants:
· The participation in the project was a highlight of my academic journey.
· It was a fantastic experience for me to turn my idea into a real thing.
· The project brought together my passion for engineering and sustainability.

Some Comments from Participants' Employers:
· The student developed a battery management system for secure the safety and efficiency of battery pack usage.
· The student made use of mechanical skills on design the aerodynamic and suspension design of cars and proved the success in the WSC.
· The student is willing to seek, listen, accept and act on the advice from different students.

Further Development

In order to further study the effect of the project on the student participants, other continuous measurement methods will be applied to the new cohort of students. The contents of the ESP and API will also be revised to cover more aspects for the study. Pre-event and during-event surveys that students joined at the beginning, and mid-term, will also be recorded for further analysis. Thus, a more complete and detail study can be conducted in the future.

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EDUCATIONAL COLLABORATION
BETWEEN CHEMISTRY AND BUSINESS DEPARTMENTS
- PARTICIPATION IN A NEW DRUG DELIVERY DRUG PLANNING CONTEST-

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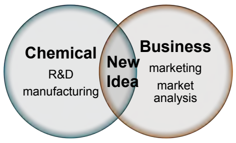
Abstract

This research aims to share a case study and the knowledge of how a single objective can be achieved through collaboration between students of the Department of Chemical and Biological Engineering and the Department of Business Administration by using and complementing each other's expertise. The students participated in the academic conference's student research contest. All of them are awarded there and in the National Institute of Technology in 2022.
This form of collaborative education demonstrates a high degree of originality. The joint research by faculty members and students from different fields and of both genders, ideas that each of them could not have generated singly became possible to generate and with success. To accomplish this, communication and mutual respect fields and division of work must be clearly defined.

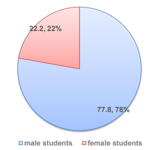
1.Background

Markets in developed countries are becoming saturated, and consumer preferences are diversifying. Companies, therefore, attempt to shorten product life cycles in response to these consumers. To speed up product development, engaging in multifaceted communication with the market from technology development and marketing has become necessary. Cross-cultural integration in product development plays an essential role in this process.
Innovations can emerge by shifting development from a male-centered perspective to one including female perspectives. Companies too have expressed a desire for female engineers (Yanagisawa, 2022). signifying the importance of the perspectives of female researchers sought by the industry.

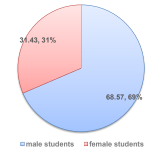
Two rare faculties at Ube College



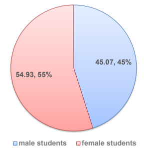
Ratio of male to female students in National Institute of Technology



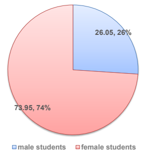
Ratio of male to female students in Ube National Institute of Technology



Ratio of male to female students in Ube National Institute of Technology Chemical and Biological



Ratio of male to female students in Ube National Institute of Technology Business

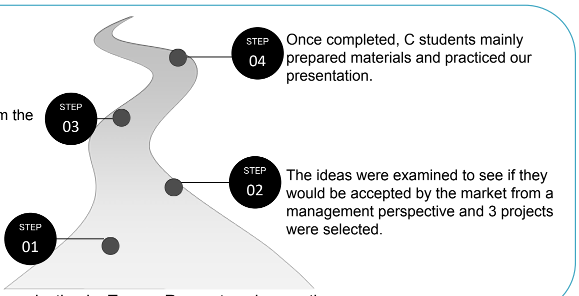


Low rate of female students in the National Institute of Technology. But a Relatively high percentage of female students in the Chemical and Business faculties in Ube college

2. Contest and Project

The Japan Society of Drug Delivery System (DDS)
An organization for presenting ideas utilizing DDS technology under the theme of medicine and pharmaceutical sciences. (DDS enables drugs to work in targeted places and at targeted times in the body).
This project: "Create Your Laboratory, Create Your Pharmaceutical Company"
to cure unresolved diseases and to improve human health.
First selection: for college students and one for high school students. In the college student section, students first make an audio/video presentation and submit it. High school students submit an essay on " Learn about DDS Technology and Propose Your Idea," and if selected, they present their idea in the same contest.
Second selection: Selected students present their ideas for solving current medical issues.

3. Work Process and Methods



STEP 01
C students took the lead in proposing product development ideas based on existing technologies and presented B students

STEP 02
The ideas were examined to see if they would be accepted by the market from a management perspective and 3 projects were selected.

STEP 03
For each project, develop ideas from the perspective of each field.

STEP 04
Once completed, C students mainly prepared materials and practiced our presentation.

Communication by Teams. Respect each expertise

5. Results, Conclusion, and Limitation

The two teams: the Grand and Third prizes in the high school division. The other team: was conferred with the President's Award in the university student division, and was also awarded a prize at the National Institute of Technology in 2022.

4. Three Projects

Huff Huff Protect

- Hand cream with sunscreen
- Frequent hand washing during the pandemic
- Although hand creams contain moisturizing ingredients, their ingredients make the hands more susceptible to sunburn. Sunscreen creams, on the other hand, contain ultraviolet absorbents and ultraviolet triphosphates, which have a low moisturizing capacity. Solve this technically.

Kproppe-ta

- The gargling time to remove the virus varies from 15 to 60 seconds, making it difficult to know when the virus can be removed entirely.
- Tell the user when to gargle and the timing to remove viruses by producing a chemical sensation in the mouth.
- The "Koroppe-tai" has two functions: to signal the end of gargling immediately after use and to signal the time for the next gargle; hence, the capsules to be mixed are a soft type (ingredient: gelatin) that breaks easily, and a hard type that breaks after 6 hours

Colorful Pee

- Against the backdrop of the need for early detection of cancer, ColorfulPee proposes the development of a supplement to detect cancer in urine.
- If there is no cancer, the micelles (cancer test drug) contained in Colorful Pea are discharged from the body as is, but if cancer is present, the micelles disintegrate in the cancer cells, and the fluorodeoxyglucose-linked dye in the micelles is contained in the urine, resulting in red fluorescent urine. Currently used cancer test self-kits are expensive and time-consuming to test.
- This product is a low-cost, easy-to-use cancer test against the backdrop of growing interest in dietary supplements

First, owing to the different timetables of the two departments, there were instances when more than one communication between students was required. This could be resolved by facilitating interactions between the two departments, such as organizing an icebreaker activity, before the event.
Second, despite the majority of participants being female students, there were no groups of male students; therefore, it was not possible to clearly identify the presence or absence of original ideas from female students. From the following year onward, it may be necessary to devise ways to organize the groups in order to evaluate potential differences in "product development" between male and female students.

6. Acknowledgments

This study was supported by "GEAR 5.0," a research project of the National Institute of Technology (KOSEN), which focuses on enhancing the social implementation education of future technology.

Intensive carrier design & Innovative research project - a new curriculum of the advanced course of the National Institute of Technology, Tokyo College-

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Tomohito Ide, Shinya Suzuki, Tomoyuki Murase, Sakurako Hiroike, Tomoyo Mitani, Susumu Tarao

National College of Technology, Tokyo College

At the advanced course of the National Institute of Technology, Tokyo College, we are always aware of the impact that science and technology have on the environment, and we aim to develop the ability to apply the specialized knowledge and technology that we have acquired in a complex and integrated manner and implement it in society. In order to cultivate students, a period of independent activities such as PBL is provided in the latter half of the first year of the advanced course.

During this period, the "Intensive career design" is arranged. Students create their implementation plan for an "Innovative research project" according to students' interests. In addition, after conducting activities according to this implementation plan, students will review their activities at the presentation held in the second half of this course and receive a wide range of opinion.

The "Innovative research project" is also arranged. In accordance with the implementation plan, under the support of a group of mentor faculty members, we will conduct activities that combine social implementation, long-term internships (collaborative research type, overseas), and creative research.

These subjects allow students to have an image of careers that can make the most of their individuality and interests and serves as an opportunity to think about their own life plans.

This year is the first year since the introduction of this new curriculum, and it will take more time to verify its effectiveness. According to the students who experienced the first year, this subject was difficult, but they had the impression that it was worthwhile and they learned a lot.

Keywords
Social implementation, Carrier design, Internship, Career education,

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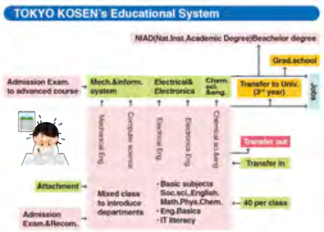

Flamework of the Intensive carrier design and Innovative research project

At the second half of the first year of the advanced course, students take two important compulsory courses.
1. Intensive carrier design
2. Innovative research project

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Intensive carrier design

10 required credits
1st week WS①, 2nd week WS②, 3rd week plan submission
4th to 13th week weekly report sharing meeting, 14th week WS ③
Review WS, 15th week presentation
Students design their own timetable in line with their career design
[MUST] Weekly report sharing meeting with colleagues for 90 min a week

A Study plan will be created through a workshop on how to combine the three activities with the support of a group of mentor faculty members placed across majors.

Support from mentor faculty
Students make a study plan
Presentation

In the first workshop, after receiving guidance on specific methods for combining social implementation, long-term internships, and creative research, students will actually create their own implementation plan. As a preliminary review, work on self-analysis and self-analysis is carried out to deepen one's understanding of oneself. In addition, as a supplementary material for the final review of independent activities in the second half of the first year of the Advanced Course, students will take a simple test on Grit and basic skills as a member of society.

The second part of the workshop will be a presentation and question and answer session on their action plan in front of a group of other students and mentor faculty. In addition to social implementation, long-term internships, and plans for creative research, presentations should include their strengths and weaknesses based on self-analysis and self-analysis, and what they want to develop and develop in the future. They will give a presentation on the capacity development plan in a broad sense. Students are required not only to make their own presentations, but also to actively ask questions to other students. Finalize the implementation plan after considering the points pointed out in the question and answer session at the presentation.

Make revisions to the plan based on the instructions for creating the plan, and have at least two mentors review and revise the plan until the next workshop (by the date of submission of the plan for the second workshop).

Self-analysis/other-self-analysis worksheets, Grit, and the results of the basic ability test for working adults must be submitted as workshop activity records. In addition, the implementation plan created at each workshop should be submitted as a record of implementation plan creation in a format that shows the revision history.

In the retrospective workshop, a retrospective sheet will be created and a presentation will be held. In preparing the review sheet, the group of mentors presents a review sheet that summarizes the overview of the overall independent activities in the second semester of the first year of the advanced course and the results of improving one's own abilities. Take a simple test on Grit and the basic skills of a working adult, and use it as a supplementary material for review

An example of their study plan
1. about my abilities
1.1 Recognition of the current situation
1.2 Grit and Basic Skills for Working People
1.3 Identifying gaps between ideal and reality
2. Setting Commitments, Milestones and Action Items
2.1 Capability improvement measures necessary to close the gap between the ideal and reality
2.2 Commitments, Milestones and Action Items to Achieve Capability Improvement
3. Activity plan
3.1 Overall schedule
3.2 Weekly Activity Plan (4th to 13th week)

Final goals of this study
1. How can I contribute to the realization of a sustainable society?
2. What are your strengths in social implementation-oriented activities?
3. How will I survive in the global world?
4. Do you have a clear career path for yourself?

An example of a student's timetable

	mo	tu	we	th	fr
1	Creative research -Experiment design and planning	Social implementation	Global activity	Creative research-Experiment	
2					
3					
4			Intensive carrier design		Weekly report meeting
			Creative research-Data analysis		

At the final presentation, the results of the activities will be presented and a summary will be prepared, and a wide range of comments will be received. It should be noted that the results of activities refer not only to specific activity results, but also to results related to the improvement of one's own capacity in a broad sense. In addition, at the end of the presentation, students will declare what they want to be in the future and their vision, and summarize the overall independent activities in the second semester of the first year of the advanced course.

Other related activities

[Group discussion]

Intensive Career Design and Innovative Research Projects require more than ever student-led learning. Through group discussions, students were asked to think about what kind of activities they would like to undertake in order to realize their careers in 10 years.
There was a lively exchange of opinions on the whole, partly due to the opportunities for group work and group discussions across departments in multiple subjects in the first semester.
They are able to share not only information about career paths after graduating from advanced courses, such as entering graduate schools in Japan and overseas and finding employment, but also about the problems and issues I had.
Concrete activities for the second semester already based on the desired course after graduation
While some students were able to explain the content, some students were still vague about the content.
➡Regular status reporting and sharing by the whole grade prevents students from becoming isolated, and listening to other students makes it possible to understand their own problems and issues relatively.

Innovative research project

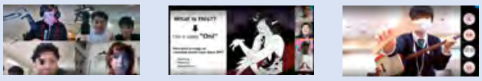
8 required credits
4th to 13th weeks social implementation activities/creative research activities/global activities
Students design their own timetable in line with their career design

[MUST] The timetable includes global activities and social implementation education

In order to realize a sustainable society, students will always be aware of the impact of science and technology on the environment, and cultivate the ability to apply the expertise and technology they have acquired in a complex and integrated manner and implement it in society. Acquire the ability to continue learning proactively and cooperatively.

[Global activity]

Three 60-minute online exchanges with Japanese language program students at the University of South Florida, USA



As a carrier lecture, Lectures and question-and-answer sessions by globally active engineers Mr. Amy He (Atwell.LCC) was invited in 2002.

As an e-learning program, Students participate in an off-campus E-learning program called ATR CALL BRIX and take courses that match their level.

https://www. Atwell-group.com/

[Social implementation]

Professors in charge: Mentor faculty (& Research supervisor)
Implementation details: With a focus on collaboration with others, under the guidance of mentor faculty members of other majors, or students independently implement social implementation activities across majors. Joint implementation with the regular course is also possible
Note: Internships with social implementation elements at partner companies, universities and research institutes are also acceptable. In addition, it is also possible to cooperate with the development group and receive feedback from a third party at the dispatched destination, research research on the social background related to the creative research activity theme, research research on regional issues at the study abroad destination, etc.

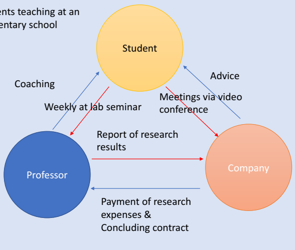
https://www.Uchida.co.jp/education.solution/atrcall-brix/

- Social Implementation Education can be thought as an engineering education to accelerate innovation.
- In the first step, students are understanding issues.
- Next, they are trying to design and build the prototype.
- Then, they apply them to society and test them in the real world.
- Finally, they get feedback from users.
- Repeatedly, improving them like PDCA cycle.

Students teaching at an elementary school

[Creative research]

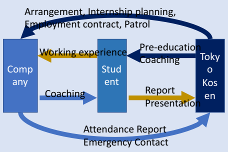
Professorss in charge: Research supervisor, mentor faculty
Implementation details: Based on the career path desired by students, implement creative research activities that allow students to acquire skills and experience that will contribute to their own growth.
Points to note: Depending on your preference, the topic may be the same as the special research, or it may be a joint research internship with a university or research institute, but the content should be conducive to your own career and growth.



Relationships and Roles of Students, Teachers and Companies

[Internship]

Students experience an internship of at least one month mainly during summer vacation



As a cooperative education, internship is also effective program.
All students are expected to participate in internship. This is a subject required for graduation.
1. Professors in Tokyo KOSEN coordinate companies cooperating with our education. Students select the company they want to go to from a list of companies.
2. Before the internship, we do pre-education for them.
3. Then, they have working experience for two weeks in the summer vacation of the fourth year.
4. During the internship period, company is coaching the student.
5. Finally, the students must submit the report and make a presentation in Tokyo KOSEN.
Sometimes, this kind of internship program is performed under joint research project. This kills two birds with one stone.

I, the first author, am a supervisor of a student majoring in the chemical science and engineering. I coordinated the student's external activities and guided him in compiling his research findings. The student did research at an off-campus research institute for 20 days during the summer vacation as an internship. The results will be presented at an academic conference in March this year.

ISATE2023: 16th International Symposium on Advances in Technology Education, 12-15 Sep. 2023, Matsue, Japan

Entrepreneurial talent development program for Kosen students

Naoyuki Akashi, Norifumi Terui, and Kazuki Sato
National Institute of Technology, Ichinoseki College

1. Introduction

Starting a business is now attracting attention as a driving force for the future of Japan. National Institute of Technology (NIT) is expected to produce human resources who can bring about innovation. In order to develop such human resources, NIT Ichinoseki College (Ichinoseki KOSEN) has been offering entrepreneurial talent development program since 2018 with the support of donations from local companies. In this program, students learn the process of commercialization through a simulation of commercializing ideas that students have come up with.

2. Program content

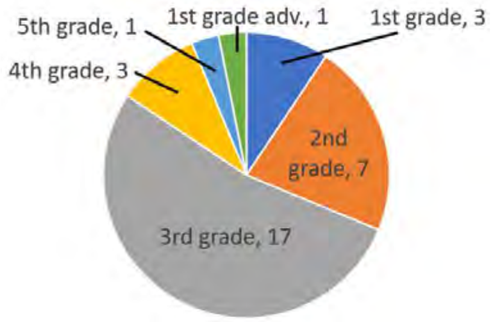
This program is recognized as an elective subject worth one credit for regular curriculum students and is conducted using after school hours. The program consists of ten lectures for two and a half hours each, with a final report meeting session at the end. Among these, lecture-style courses will be held five times (Leadership, Strategy, Funding, Marketing, and Finance), and round-table conferences inviting venture entrepreneurs will be held three times.

In addition, every time, students brush up their own business concept. In addition to discussions among students, students receive advice from a mentor. The theme of the business concept is a product, program, project, etc. that each student has thought of. While receiving advice from the mentor, students brush up their own business concept and experience the process of independently exploring the direction of commercialization. We believe that it is possible to acquire the ability to understand and accept diverse opinions, and the ability to convey one's own thoughts concisely and clearly.

3. Achievement

The program started in 2018 and has been held every year with an interruption in 2020. A total of 32 students attended the program over the four years, with an average of eight students attending each year.

So far, three of the students have started two companies while still in college.



Number of students over 4 years

4. Examples of business concept

- ✓ AR fishing pole that conveys the fun of toys to children of the smartphone generation.
- ✓ Creation of inexpensive and easy-to-use music creation tools.
- ✓ Let's reduce food loss ! Food bank activity !
- ✓ Coexistence with deer.

5. Voices of students

- ✓ I thought that starting a business is difficult and it would be impossible without a basis for absolute success, but my desire to try it became stronger.
- ✓ Usually, students don't have the opportunity to talk about starting a business, so it was very meaningful to be able to deepen discussions among students who are interested in starting a business.

Discussion with the president.

Advice from the mentor.

Discussion among students.

Maritime career education through collaboration between five KOSENs and industry organizations

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Introduction

Five of KOSENs (Toyama, Toba, Hiroshima, Oshima, and Yuge) have departments of maritime technology.
The departments provide education and training to students to be officers and engineers of merchant ships. These are licensed professions and important to the global economy.

The five KOSENs also provide career education to the students to deepen their understanding of the maritime professions. Some of the career education programs are conducted under the direction of the "*Council for the Development of the Next Generation of Maritime Human Resources at National KOSEN*". The council is composed of the five maritime KOSENs, two maritime universities, and organizations related to the marine industry and marine education.

The Japanese Shipowners' Association
Japan Maritime Officers' Association
All-Japan Seamen's Union
International Mariners Management Association of Japan
Japan Agency of Maritime Education and Training for Seafarers

Collaboration for Maritime Career Education

Toyama College
Toba College
Hiroshima College
Oshima College
Yuge College

Textbook and Workbook

In 2009, a textbook on maritime careers was written by faculty members of the five KOSENs and other contributors, and it has been available for the students. And a workbook also has been available to record the license examinations, training at sea, lectures, seminars, and so on.

Seminars for career education

In 2015, a seminar was held with invited five speakers from four organizations related to the marine industry.
The seminar was attended by 464 students from five KOSENs via videoconferencing system.
Since then, such special seminars have been held every year up to the present.
In 2022, the seminars were held with invited speakers from five organizations, at each of the five colleges in face-to-face style, and recordings of the seminars were shared to the other colleges.

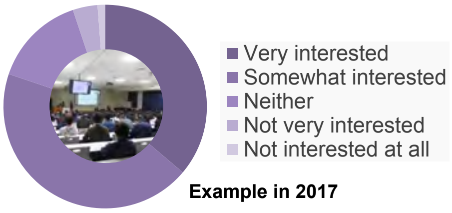
These seminars have covered the following topics:

- Specifics and benefits of maritime jobs
- Attractiveness of shipping companies
- Activities of the seafarers' trade union
- Career examples of past graduates of the colleges
- Preparations for training at sea

Numbers of Attendees

2015	464
2016	83
2017	522
2018	522
2019	397
2020	407
2021	497
2022	488

Example in 2017	Toyama College	Toba College	Hiroshima College	Oshima College	Yuge College
1st year students	39	40	37	38	
2nd year students	45		46	40	
3rd year students	31	32	39	38	46
Seniors, Parents, etc.	23				28



Example in 2017

Responses of Attendees

Conclusion & Outlook

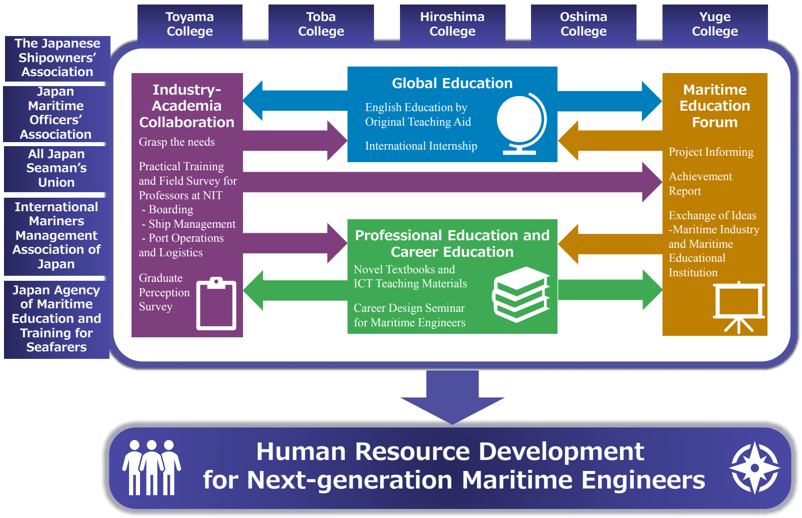
Our career education has been considered to be effective in motivating the students to engage in the training while in college, and in motivating them to work at sea after graduation. And the five KOSENs are currently studying the recent changes in the career aspirations of young people in Japan, and discussing how the career education should respond to these changes.

The Feature of Maritime Education at KOSEN and the Collaboration of the Five KOSENs

○Sachio KUBOTA (NIT, Toba College), Kiichiro MUKOSE (NIT, Toyama College)
Tomoyuki HAMADA (NIT, Hiroshima College), Jongdoc PARK (NIT, Oshima College)
Akira FATAMURA (NIT, Yuge College)

Introduction

The feature of the maritime education at KOSEN, which is a common Japanese name of National Institute of Technology, is the practical education utilizing training ships and training equipment. The students learn technology not only through classroom lectures but through practical training. Various skills and capabilities are required for maritime engineers involving seafarers and related engineers. These skills and capabilities vary with the periods. Therefore, some projects are carried out by the collaboration of the five KOSENs, which include global education, career education, generic skill education, and faculty development. This poster will present some results of these projects.



Toyama College | Toba College | Hiroshima College | Oshima College | Yuge College

The Japanese Shipowners' Association
Japan Maritime Officers' Association
All Japan Seaman's Union
International Mariners Management Association of Japan
Japan Agency of Maritime Education and Training for Seafarers

Industry-Academia Collaboration
Grasp the needs
Practical Training and Field Survey for Professors at NIT
- Boarding
- Ship Management
- Port Operations and Logistics

Graduate Perception Survey

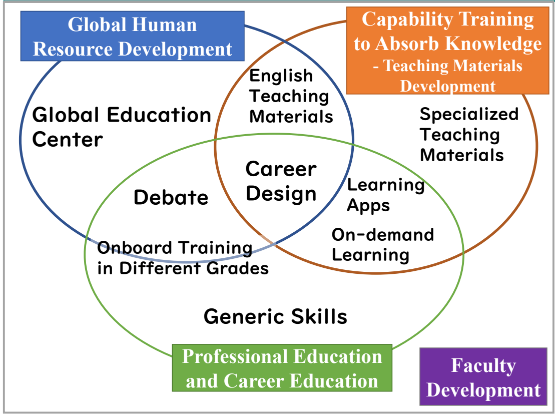
Global Education
English Education by Original Teaching Aid
International Internship

Professional Education and Career Education
Novel Textbooks and ICT Teaching Materials
Career Design Seminar for Maritime Engineers

Maritime Education Forum
Project Informing
Achievement Report
Exchange of Ideas -Maritime Industry and Maritime Educational Institution

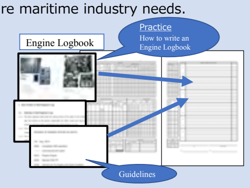
Human Resource Development for Next-generation Maritime Engineers

The Policy of Human Resource Development for Five KOSENs at Maritime Technology

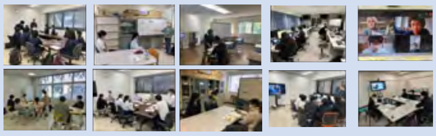


Global Education

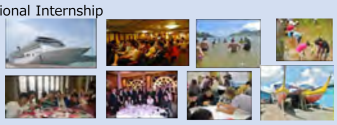
●We are developing practical English education materials to meet future maritime industry needs.



●English learning lectures
Five colleges are mutually connected by the video conference system.



●International Internship



Teaching Materials Development

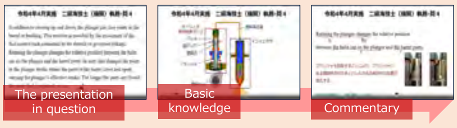
- The teaching materials of various specialized subjects required for related fields of maritime technology have been issued as "Maritime college series".

- Teaching materials are published by the professors of five KOSENs.

- The on-demand video teaching materials are produced for supporting self-study. (The number of contents: Approximately 100 (as of March,

Outline of System

Composition which used some applications (OneDrive, Stream, Teams) of Microsoft Corp.



Career Education

- Career Design Seminar for Maritime Engineers

- The career meeting by graduates

- Mixed-Grade Classes –Onboard Training

- Academic debate

Faculty Development

Background

○**Diversification of Professors**

- The increase in the number of professors who have not graduated from maritime educational institutions
- The increase in the teachers who do not have an experience in actual business as a ship officer

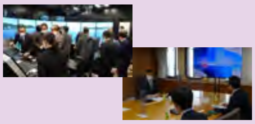
○**Acceleration of technical innovation in the shipping industry**

- Autonomous operation technology
- Promotion of Development and Use of Ocean Resources

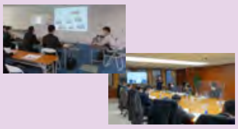
Improvement in educational capability

The facility tour

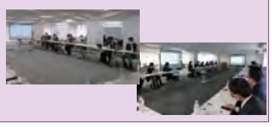
- The DP training center
- The support center from the shore



- The effort towards zero emission
- International rules for autonomous ship



Skull session with staff of coastal shipping



Conclusion and Future Work

- In order to continue responding to the needs from the shipping industry, the education system for cultivating superior human resources has discussed by industry-Academia collaboration.
- In the future, we would like to develop the educational system corresponding to the innovation of maritime and ocean field. We are going to support multilaterally the career design of the students who aspire after the shipping industry.

International exchange programs of training maritime cadets in collaboration with five maritime KOSENs

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Keywords: *Collaboration, Maritime cadet, Maritime KOSEN, MAAP, SMA, KCC, Online program*

Education for Global Competence Enhancement

Short Description:

The collaboration of training international cadets and developing a global internship program was implemented by Japanese maritime KOSEN. In this work, we are going to report the international exchange programs prepared in collaboration with five maritime KOSENs and Japanese international organizations of shipping. There are three programs here, Maritime Academy of Asia and the Pacific (MAAP) program, Singapore Maritime Academy (SMA) program, and Kaua‘i Community College (KCC) program. It has been a good educational effect on Japanese students so far. This activity reviewed how the international exchange programs worked for training maritime cadets.

Shipboard training view of the engine cadets (Japanese and Filipino) on training ship M/V KGO from MAAP

Schools and places		Period Days	Price USD	Programs	Number of Japanese participants Year					
					14	15	16	17	18	19
MAAP (Maritime Academy of Asia and the Pacific) of Philippines	Japan	14	0	Maritime English Seminar Collaboration to onboard training	840	630	–	–	–	29
NTMA (NYK-TDG Maritime Academy) of Philippines	Philip-pines	11	700	Special English seminar Attend regular classes, Field Trip	–	4	9	10	23	16
Singapore Maritime Academy of Singapore	Singap-ore	14	3000	English Seminar Maritime experiential learning camp	16	13	8	16	cancelled	cancelled
Kauai Community College of U.S.	Hawaii	21	4000	Polynesian traditional voyaging Campus activities	11	16	12	11	10	cancelled

International internships and maritime English programs of five maritime KOSENs

1. Current Status and Future of International Exchange with the Philippines

MAAP has developed the global educational programs such as “Maritime English Seminar” and “the short cross-cultural Onboard Training” (see photos). The partner maritime academy, NTMA and MMMA are included as other international exchange parties. NTMA & MMMA were established by major Japanese shipping companies.

As shown in the table, the participants are increasing gradually because it is a affordable price in the Philippines.

The five maritime KOSENs have developed the English training and global internship program in the Philippines which is affordable for Japanese maritime students. The collaboration programs was successful.

Training ship M/V KGO (Kapitan Gregorio Oka) from MAAP

2. International internship program with Singapore Maritime Academy (SMA)

The internship program with SMA at Singapore Polytechnic has developed since 2008 when the Toba College first concluded international academic and educational exchange agreement. In this program, the maritime KOSEN students joined the Maritime Experiential Learning (MEL) Camp held by SMA. Before the MEL Camp, the students attended English conversation class to get used to communicating with SMA students.

Also, the students had a chance to visit Japanese shipping companies in Singapore. During the MEL Camp, the students took onboard a large cruise ship and participated in the lessons and workshops with SMA students.

Onboard training (MEL Camp) at Singapore

Visiting Japanese shipping company at Singapore

Maneuvering simulator training at SMA

3. International internship program with Kaua‘i Community College (KCC)

The five maritime KOSENs and KCC in Hawaii have collaborated since 2009. Three-week program about Polynesian traditional voyaging, specially developed for maritime KOSEN students was held in March every year.

The program was held for 10 times from 2010 to 2019, and 110 students in total have participated in the program.

On 1st to 2nd week: The theories of Polynesian traditional on the actual voyaging canoe of “Namahoe” (see photo).

On 3rd week: The crew training for Hawaiian people at the ocean with great nature on Kaua‘i.

Since 2020, we have developed and started the alternative online program because of COVID-19. The program was held for three times from 2021 to 2023, and 49 students in total have joined.

As the pandemic has finished, the real program has been started at Kaua‘i this summer. 14 students are participating the program until 15th September in 2023.

Actual voyaging canoe of “Namahoe” at KCC

UAV Surveying Exercise in Akashi Kosen for the Future Construction Industry

National Institute of Technology,
Akashi College, Civil Engineering
Yasuyuki NABESHIMA and Ami IKUTA

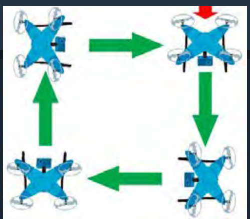
UAV Surveying Exercise

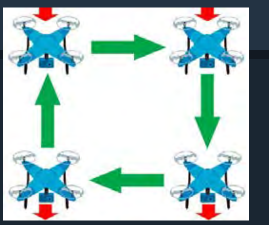
Photogrammetry is one of main subjects in Applied Surveying. The 3D-point cloud data by using SfM analysis from multiple photographs is a key to learn in this subject for i-Construction. Students in Civil Engineering are learning the photogrammetry surveying techniques with UAV and the operating techniques of UAV. The UAV operating exercise are carried out in the gymnasium because our college is located in “Densely Inhabited District (DID).”


DJI Phantom RTK

Two DJI Phantom RTKs are used in this exercise. All students are able to operate UAV by themselves.

Fundamental exercises of UAV operations are for beginners. For Exercise 1, the operation of UAV to trace the square course as UAV front nose was the same as a course was exercised. This is the first step to operate UAV, it can be done by only two simple actions. For Exercise 2, the operation of UAV to trace same square course as UAV front nose was always kept to the original direction was exercised. This is the second step to operate UAV, it also can be done by only two actions. For Exercise 3, the operation of UAV to trace the circle course was exercised. It is a little difficult for beginner to operate UAV because of the complex actions. UAV trace along the circle course with the front nose facing the center of the circle. It is called as “nose in circle.” After learning UAV operation, students study photogrammetry in Applied Surveying. The authors are planning to teach surveying techniques along the public surveying manual by UAV in our college.


Exercise 1


Exercise 2


Exercise 3

ℹ

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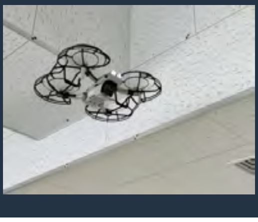
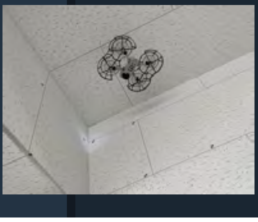
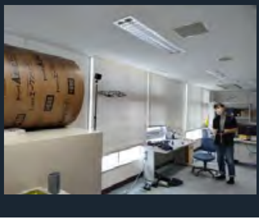
Another UAV Training

DJI Mavic Mini

Another UAV training is an inspection of structures. DJI Mavic mini, which is a small UAV among commercial devices, is used for this training. The targets on pillars and crossbeams or those in the pipes are inspected by UAV camera. Two small LED lights are installed on UAV to illuminate the targets.







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