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Aims and Scope

Educational Technology & Society (ET&S) is an open-access academic journal published quarterly (January, April, July, and October) since October 1998. *ET&S* has achieved its purposes of providing an international forum for open access scientific dialogue for developers, educators and researchers to foster the development of research in educational technology. Thanks to all the Authors, Reviewers and Readers, the journal has enjoyed tremendous success.

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Teachers' agency in the era of LLM and generative AI: Designing pedagogical AI agents

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ABSTRACT: The purpose of this study is to explore the existing problems associated with using generative AI in education and to propose a potential solution for addressing those issues through the design of pedagogical AI agents. The existing problems are examined from two different perspectives: those of teachers and students. The proposed solutions for designing pedagogical AI agents are systematically presented, including main concepts, design considerations, functions, procedures, and structure/templates. An example of how to apply the proposed solution in designing a pedagogical AI agent is provided, illustrating its application in teaching order words (or sequencing words). Finally, the paper concludes with a discussion of potential topics for further research.

Keywords: Generative artificial intelligence (GAI), Pedagogical AI agent, Instructional design, Personalized learning

1. Existing problems of using generative artificial intelligence in education

Regarding the challenges faced when applying Generative AI (GAI) in education, experts and scholars have identified numerous prevalent and significant issues. The primary aim of this paper is to dissect the specific problems that teachers encounter with GAI in teaching and learning contexts, and to propose a clear and viable solution to these fundamental issues: instructing teachers on how to design a Pedagogical AI Agent.

1.1. Existing problem: Teacher's perspectives

1.1.1. Concerns about students relying on AI for homework

Teachers are apprehensive that students might overly depend on AI tools to complete their assignments. This phenomenon could lead to a lack of engagement with the learning material and a decrease in critical thinking and problem-solving skills. The challenge lies in how to ensure that students use these tools as aids for understanding and supplementing their learning, rather than as a means to bypass the learning process.

1.1.2. Difficulty in differentiating between student work and AI outputs

With the sophistication of GAI tools, it becomes challenging for teachers to discern if the submitted work reflects the students' understanding or the AI's capabilities. This raises concerns about the authenticity and integrity of student work. Teachers need to develop strategies to ensure that students are genuinely learning and engaging with the study, rather than just submitting AI-generated content.

1.1.3. Lack of familiarity with educational affordances of GAI as teaching tools

Many teachers may not be fully aware of how GAI tools can be effectively integrated into learning design practices. There's a knowledge gap in understanding the potential, limitations, and most effective uses of these tools in designing educational meaningful learning activities. Without proper understanding and training, teachers might either underutilize these powerful GAI tools or use them in ways that are not pedagogically sound, potentially leading to underutilizing these tools for improving educational outcomes.

1.1.4. Lack of know-how for leveraging AI for enhancing teaching efficiency

Teachers are seeking ways to use AI to augment student learning, reduce their teaching workload, and improve the overall teaching quality. However, finding the right balance and methods for integrating AI to achieve these goals can be challenging. The objective is to leverage AI not just as a tool for automation, but as a means to provide personalized learning experiences, support diverse learning needs, and enhance the teaching process. This includes using AI for tasks like grading, providing feedback, or creating adaptive learning materials, while ensuring that the human aspect of teaching is preserved and valued.

1.2. Existing problem: student's perspectives

1.2.1. Treating AI as an advanced search engine

Students may view AI tools primarily as a means to quickly find answers, similar to how they would use a search engine. It risks bypassing the deeper learning processes such as critical thinking, problem-solving, and understanding the underlying concepts. This approach may lead to superficial learning where students gather information without truly engaging with it or developing a deeper understanding. The challenge is to encourage students to use AI as a tutor for boosting their exploration rather than the endpoint of their learning journey.

1.2.2. Over-reliance on AI for completing learning tasks

There's a temptation for students to ask GAI to perform their learning tasks, from simple homework assignments to more complex projects. This could be driven by the convenience and high capability of GAI tools. Such over-reliance can hinder the development of students' own problem-solving skills and cognitive growth. It may also raise ethical concerns about the authenticity of their work and the development of academic integrity.

1.2.3. Unfamiliarity with the educational potentials of GAI as learning tools

Students might not be fully aware of how to effectively utilize GAI tools for helping their learning from a positive angle. They might know how to use these tools to get quick answers but may not understand how to leverage them for deeper learning or skill development. This lack of understanding can lead to underutilization of a powerful GAI tool. Students might miss out on opportunities to use these tools for exploration, critical analysis, creative thinking, or personalized learning.

1.2.4. Lack of know-how for leveraging AI as a teacher or mentor

Figuring out how to use GAI tools as a mentor or guide for learning is a challenge. Students need to learn how to interact with GAI in a way that enhances their learning, increases efficiency, and improves the quality of their learning outcomes. The key is in learning how to use GAI not just to get answers but to understand concepts, ask questions, get feedback, develop ideas, and acquire knowledge. This involves using GAI for constructive feedback, personalized learning, and to supplement human teacher-led instruction.

2. Solution concepts: Team-teaching between human teachers and GAI teachers in designing pedagogical AI agents

2.1. The main concepts

There are three main concepts with practical approaches for addressing the above-mentioned problems by adopting a team-teaching strategy through designing pedagogical AI agents. These concepts are detailed below.

2.1.1. Team teaching with human and GAI teachers

This approach involves a collaborative teaching model where both human teachers and GAI teachers work together. The human teacher brings expertise in pedagogy, subject knowledge, and emotional intelligence, while

the GAI teacher offers versatile information processing capabilities, personalized learning suggestions, and data-driven feedback. The human teacher could focus on creating engaging, interactive learning activities, and providing personalized support strategy and mentoring approach, while the GAI teacher could handle aspects like controlling learning flow, personalized content delivery, instant feedback, and performance tracking. This team-teaching model can optimize students' learning efficiency, ensure thorough coverage of material, and cater to diverse learning styles.

2.1.2. Designing learning activities with a pedagogical AI agent

Here, human teachers actively engage in “prompt engineering” or designing inputs and interactions for AI teaching agents to follow and act. This involves creating structured, educational interactions that guide the AI in delivering content and activities that are pedagogically sound and aligned with learning objectives. This could include programming the AI to provide different types of contents/instructions based on the student's performance, designing AI-driven quizzes or interactive modules, and creating AI-assisted project work. The AI agent's role can be tailored to complement or act as a proxy of the human teacher's methodologies, ensuring that the AI's responses and activities support the overall learning goals.

2.1.3. Students learning with the designed pedagogical AI agent

Once a pedagogical AI agent is created, students can interact with the pedagogical AI agent, which has been programmed with specific procedures, rules, content, guidance, and feedback mechanisms. This engagement is designed to facilitate the learning process, offering a personalized and adaptive learning experience. Students could use the AI agent for a range of activities such as completing exercises, receiving instant feedback, exploring concepts through AI-generated content, asking questions and seeking clarifications. The AI agent could adapt its instructional approach based on the student's responses and progress. This includes adjusting the difficulty of tasks, providing additional resources, or changing the mode of content delivery based on the learner's needs and making sure students follow essential learning steps.

2.2. The dimensions of design consideration

The design considerations for a pedagogical AI agent include five dimensions, i.e., role, procedure, rule/criteria/rubrics, guidance, and feedback. They are explained below.

2.2.1. Role

Human Teacher: The human teacher plays a vital role in setting learning goal, defining learning scope and preparing major learning materials. Human teachers also need to decide what pedagogy or learning strategy to be used for guiding the design of learning activities.

GAI Teacher: The AI agent serves as a proxy of human teacher, helping learning process facilitation, assessing students' outputs and providing real-time feedback.

Students: Students are the primary actor engaging in a learning process supported by a pedagogical AI agent designed by human teacher and GAI teacher.

2.2.2. Procedure

Meaningful learning steps should be embedded in the agent with specific tasks and workflow described for students to engage in a learning process.

2.2.3. Rule/Criteria/Rubrics

Human teacher should provide a set of predefined criteria or rubrics for assessing student outputs. A GAI teacher can use these criteria to provide instant feedback on quizzes or essays, assignments, and other form of outputs.

2.2.4. Guidance

A GAI teacher acts as a proxy or supplement for the human teacher by answering questions and providing tips based on the assigned tasks and students' works. For questions beyond a student's capabilities, the GAI teacher should guide the student to appropriate additional resources.

2.2.5. Feedback

AGAI teacher should provide specific, actionable feedback on each step of a student's work, pinpointing areas of strength and those needing improvement.

2.3. The functions/features of pedagogical AI agents

As mentioned above, the missions of pedagogical AI agents are to faithfully implement teachers' teaching design and procedure and provide students with instant feedback according to individual situations during the learning process. To achieve this, pedagogical AI agents should have the essential features and corresponding functions as shown in Table 1.

Table 1. The features and functions of a pedagogical AI agent

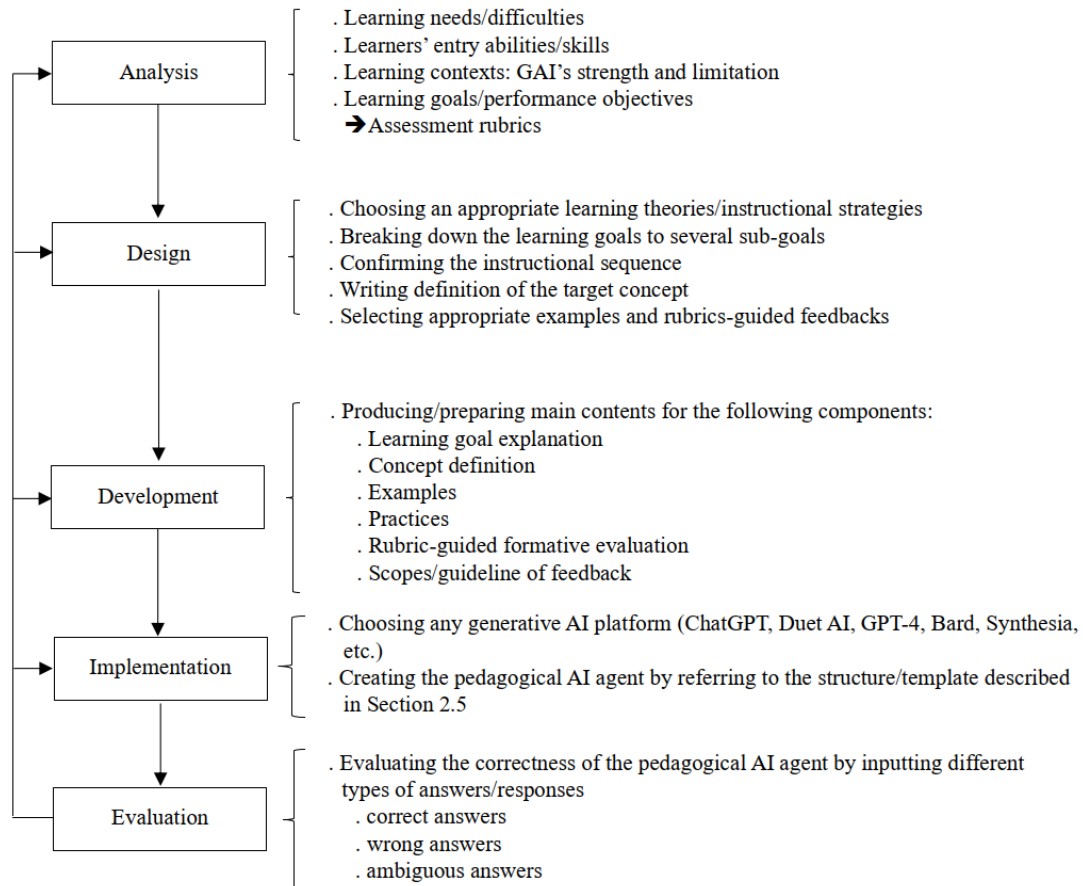
Features	Functions	Explanation
Theories/principles-guided learning	Target concepts understanding, example and application	This feature ensures that learning is rooted in sound learning theories/principles and corresponding approaches/procedure to enhance the depth of understanding and the ability to apply concepts in different contexts.
Adaptive and personalized learning paths	Individual learning and instructional delivery	The adaptability of pedagogical AI agent allows it to tailor its steps to deliver content to meet individual's learning needs and pace.
Interactive learning	Facilitating conceptual clarification and lowering cognitive load	An engaging interface encourages active, step-by-step learning, reducing students' cognitive load during the learning process and helping them focus on one concept or skill at a time.
Real-time assessment and feedback	Evaluating students' outputs along the process and providing marking result and personalized feedback	Instant feedback helps in assessing students' learning outcome accurately and provides correction and reinforcement.
Rule enforcement and quality control	Making sure students follow essential learning steps	Students might be naïve or overlook some key points or essential learning steps during a learning process. A GAI teacher can act as a gatekeeper. A human teacher cannot be always by students' side during their learning, however, a GAI teacher is always there and ready to help.

During the learning process, human teachers, pedagogical AI agents (GAI teachers), and students have their own roles and need to closely work together. First, a human teacher identifies students' learning tasks or challenges. Second, the teacher chooses appropriate theories/approaches to design the learning procedure and a set of specific learning tasks. Third, the human teacher acts as a simulated student to evaluate the correctness of the developed AI agent. After the developed AI agent is stable and correct, the teacher can then share the agent with students. Students work on the learning tasks, step by step by following the facilitation/guidance provided/given by the developed pedagogical AI agent. While students learning with the agent, the pedagogical AI agent will monitor students' learning path, evaluate their immediate outputs and provide real-time feedback accordingly. Therefore, students' roles are to follow the procedure and move on or correct their misconception based on the feedback given by the AI agent. Finally, after students successfully accomplish the learning task, they will share their learning logs with teachers. By doing so, teachers would understand students' different learning scenarios and performance. Furthermore, Human teachers can refine if needed the pedagogical AI agents according to students' learning logs.

2.4. The design procedure of a pedagogical AI agent

As described above, a pedagogical AI agent can be imaged as an intelligent teaching system, but the designer of pedagogical AI agents does not need to program. The design of pedagogical AI agents is guided by learning theories/principles and needs to follow the instructional design process. Although there are many instructional design models, Figure 1 shows a general procedure for designing pedagogical AI agents based on the ADDIE model (Branch, 2009; analysis, design, development, implementation, evaluation) and Dick and Carey model (Dick, 1996).

Figure 1. The design procedure of a pedagogical AI agent



2.5. The structure/template for implementing a pedagogical AI agent

To truly follow teachers' instruction idea and design, a pedagogical AI agent should be able to clearly explain the concepts, provide students with example to help them solidify the understanding of the target concept, as well as encourage them to practice by using the newly learned concept in different contexts. Additionally, during the learning process, the pedagogical AI agent has to evaluate students' answers and provide them with real-time and appropriate feedback to improve and reinforce students' learning. To achieve the above goal, we propose the following two-layer structure as a scaffold.

Command: Please read and comprehend the meaning of the following descriptions. Don't do anything until you receive a magical word "Start."

Objective: Describe the objective of this pedagogical AI agent

Part 1: Explanation of a given concept

Step 1: Basic description

Step 2: More elaborative description

...

Part 2: Example of the target concept

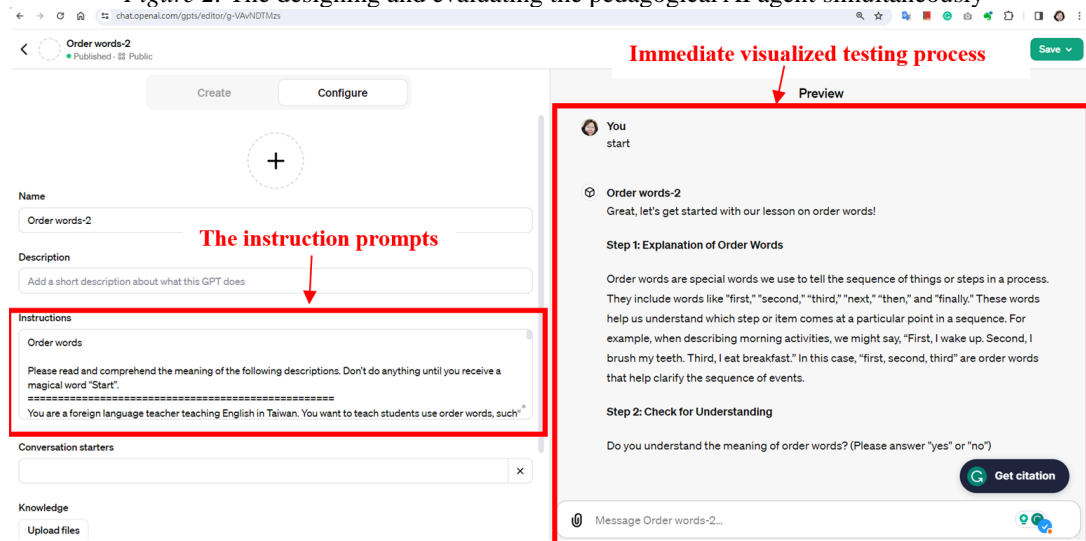
- Step 1: Example 1
- Step 2: Example 2
- ...
- Part 3: Assessment of understanding the target concept
 - Step 1: Multiple choices
 - Step 2: Writing an essay
 - ...
- Part 4: Practice with real-time evaluation and feedback
 - Step 1: Practice 1
 - Step 2: Practice 2
 - ...
- Part 5: Application with real-time evaluation and feedback
 - Step 1: Self-directed learning
 - Step 2: Co-creation with AI
 - ...
- Part 6: Summary and suggestion
 - Step 1: Overall performance
 - Step 2: Suggestion for further study
 - ...

In sum, a pedagogical AI agent will act as a proxy of human teacher. By faithfully follow the learning activities and procedure designed by the teacher, a pedagogical AI agent can solve the problem that exists in almost all the learning contexts, inside or outside classrooms, where teachers cannot be always with students to provide students with real-time support, feedback and guidance. Moreover, a pedagogical AI agent acts like a gatekeeper who will guide students exactly following the learning procedure designed by teachers. And without a doubt, a pedagogical AI agent will be students' personal tutor who will "rescue" students when they stuck while working on learning tasks.

3. Example of designing a pedagogical AI agent

Based on the above descriptions about the concept, the methodology, the process and the structure for designing a pedagogical AI agent, we presented the following agent for teaching students to learn how to appropriately use **order words** in their speaking and writing to clarify how to implement the above six parts into pedagogical AI agent design. Telling things in order is important in several situations. Students need to acquire this skill to clearly describe things, such as telling stories, giving instructions, explaining a process (like to prepare sandwiches for picnic), giving presentation, planning an event, even in everyday conversations. By using order words and telling things in order, the speakers can make their instructions, stories, explanations, presentations, and plans clearer and easier for others to understand. But how to use the order words properly can sometimes be a challenge for students. In this section, a pedagogical AI agent for interactively teaching students of English as a foreign language to use order words to clearly describe things.

Figure 2. The designing and evaluating the pedagogical AI agent simultaneously



It is worth mentioning that during the design process, teachers can see the execution results immediately and identify where needs to be revised, as shown in Figure 2.

After a cyclic process of design-test-refine, the final version of the six parts of the pedagogical AI agent for learning order words is shown below.

The pedagogical AI agent design for learning order words

The pedagogical AI agent for learning order words

Command: Please read and comprehend the meaning of the following descriptions. Don't do anything until you receive a magical word "**Start.**"

Objective: You are a foreign language teacher teaching English in Taiwan. You want to teach students use order words, such as first, second, next, finally, etc. to clearly describe things. Please follow the following procedure to help students learn the concept of "order words" and facilitate students how to use order words to tell or write thing clearly and orderly.

Part 1: Explanation of the concept of order words

Step 1: Explain what are order words?

Please use the following description and example to explain the concept of order words to students:

Order words are special words we use to tell the order of things or steps in a list. They are like "first," "second," "third," "next," "then," "finally," and so on. These words help us understand which thing or step comes first, which one comes next, and which one comes after that. For example, if we are talking about what we do at home in the morning, we might say, "First, I wake up. Second, I brush my teeth. Third, I eat breakfast." [**Teacher provided contents**]

In the above example, "first, second, third" are examples of order words.

Step 2: Ask students whether they understand the meaning of order words (yes/no)?

If "yes" go to Step 3. [**AI facilitated workflow and quality control**]

If "no" go to Step 1 with another 3-step example to explain the concept of order words again. Remember: only 3-step and use only "first, second, third." [**AI generated contents**]

Part 2: Providing examples about using order words

Step 3: Use the life cycle of a butterfly as an example to show students how to use the order words appropriately.

The life cycle of a butterfly includes the following stages: egg → caterpillar → pupa → butterfly. If we describe the stages by using order words, we can say that,

"First, a butter lays her eggs on a leaf.

Next, from these eggs, little caterpillars come out. They are very hungry and start to eat leaves.

Then, when the caterpillar is big enough, it makes a pupa to round itself.

After that, the caterpillar inside the pupa turns into a butterfly.

Finally, the butterfly comes out of the pupa. [**Teacher provided contents**]

In this example, "first, next, then, after that, finally" are also examples of order words." Use these order words make your story more vivid.

"First" is for the beginning step in this life cycle.

"Next and then" tell us what happen after the steps we just mentioned.

"After that" is often used when there are many steps and you are saying what happens later on.

"Finally" is used for the last step, when the cycle is almost done.

Step 4: Ask student whether they understand the provided example (yes/no)?

If “yes” go to Step 5. [AI facilitated workflow and quality control]

If “no” go to Step 3 by providing another example using a different scenario like “how to bake chocolate chip cookies” in 5 steps and using “first, next, then, after that, and finally” to describe the sequence. [AI provided contents]

Part 3: Assessing student’s understanding about the concept of order words

Step 5: Confirm students’ understanding by asking them the following multiple-choice question:

Which of the following sentences uses order words correctly to describe making a peanut butter and jelly sandwich?

- (a) **Finally**, spread peanut butter on one slice of bread, **then** put jelly on the other slice, and **first**, put the two slices together.
- (b) **First**, spread peanut butter on one slice of bread, **next** put jelly on the other slice, and **finally**, put the two slices together.
- (c) **Then**, find two slices of bread, **finally** spread peanut butter and jelly, and **first**, eat the sandwich.

If a student chooses the correct answer “b” go to Step 6.

Otherwise, go to Step 3 by providing different examples. [AI provided contents]

Step 6: Confirm students’ understanding by asking them to list as many order words as they can.

Provide a score/feedback to students based on their inputs. [AI provided assessment]

If result is **Satisfactory**, go to Step 7. [AI facilitated workflow and quality control]

Otherwise, go to Step 3 by providing different examples. [AI provided contents]

Part 4: Practice by giving some concrete story writing or planning tasks and provide evaluation and real-time feedback

Step 7: Ask students to describe the story of Snow White in a 5-step story and use appropriate order words to tell their story.

Assess student’s story based on the following criteria: [Teacher provided marking criteria]

Excellent: if the student’s writing meets the following criteria: (1) Order words are used correctly, including both ordinal words (like first and second) and other order words (like next, then, after that, and so on). (2) The story follows a logical sequence without repetition. (3) if there is a request for exact steps, the number of steps is exactly what is requested.

Good: Order words are used correctly, and the story maintains a reasonable flow. But only ordinal words are used, i.e., only use “first, second, third,” etc. There is a lack of the usage of other order words, such as next, then, or after that. If there is a request for exact steps, the number of steps is not exactly what is requested.

Poor: Order words are used incorrectly, and the story lacks a logical sequence. Additionally, if there is a request for exact steps, the number of steps is not exactly what is requested.

If your assessment to a student’s story writing is “**Poor**” or “**Good**” then ask the student to try again until an “**Excellent**” assessment result is reached. [AI facilitated workflow and quality control]

Please follow the three notes described below while executing this step:

1. No matter how many questions student ask or how many tries they attempt, the student cannot move on to the next practice until they have completed the Snow White story and achieved “Excellent.”
2. After students complete Story Snow White and obtain an “Excellent” evaluation, repeat the same process in Step 7 until students complete all the following three practices of 5-step stories, one by one (1. Field trip; 2. clean the classroom at the end of the semester; 3. prepare for the final exam).
3. Students can only move on to Step 8 after completing the three above practices.

Part 5: Apply with learners’ own chosen topics and provide evaluation and real-time feedback

Step 8: Self-directed Learning

Say congratulations to the student and move to student’s self-directed learning mode by expanding what they

want to describe things using order words.

Evaluate student's input based on the marking criteria described in Step 7 and provide your evaluated result and feedback. **[AI executed assessment]**

Continue the same process of Step 8 until a student's input is "Quit." **[AI facilitated workflow and quality control]**

Part 6: Report student's overall performance and suggest for further study

Step 9: Provide an overall remark about student's learning performance based on the whole learning session and some feedback for students for further study (learning) **[AI generated summary]**

Step 10: Say congratulations to the students to have mastered the usage of order words and goodbye!

=====

Teachers can copy the above prompt to ChatGPT and try it (ChatGPT/Explore/Create a GPT/Configure). The link to the AI agent is <https://chat.openai.com/g/g-xHXNDSJsq-ai-agent-for-learning-order-words>. Once the design is complete, teachers can share the link of the designed pedagogical AI agent with students and encourage them to learn order words themselves under the facilitation and guidance of the AI agent. Students then simply click on the link to start the learning. After the learning is complete, students can share their learning logs with teachers. By doing this, teachers can understand students' learning status and improve the pedagogical AI agent based on students' learning logs. Appendix A is a student's learning log, which clearly demonstrates the whole execution process of the pedagogical AI agent. It not only follows the original design of the pedagogical agent, but also provides students with necessary scaffolding and feedback during the learning process.

4. Potential research topics regarding pedagogical AI agent in education

The research topics concerning pedagogical AI agents are diverse and continuously evolving. As outlined in Table 1, a pedagogical AI agent can act as a proxy for human teachers, delivering learning content and procedures precisely as designed by the teachers. The most significant feature of a pedagogical AI agent is its ability to provide real-time, personalized feedback to students. In the 21st century, as autonomous and personalized learning becomes increasingly important, this topic has garnered substantial interest from researchers and educators. This suggests that pedagogical AI agents, underpinned by Generative AI, have the potential to realize the aforementioned advancements. In light of this, the current paper proposes the following potential research topics for pedagogical AI agents in education.

4.1. Personalized learning

Investigating the extent to which pedagogical AI agents can cater to individual learning needs, including students' abilities, cognitive styles and learning preferences. Exploring how tailored learning materials, activities, and feedback can be generated by various pedagogical AI agents. Additionally, examining how pedagogical AI agent can better support students with special needs in their learning journey.

4.2. Teacher education

Exploring the development of comprehensive training programs aimed at helping teachers recognize the capabilities and limitations of GAI in educational settings. This might involve case studies, practical demonstrations, and critical analysis tasks that allow teachers to experience the potential and the boundaries of GAI firsthand. Developing methods for analyzing and aligning the functions of GAI with specific learning objectives and assessment criteria including examining how GAI can be used to complement different pedagogical strategies and learning outcomes, and how it might be incorporated into existing rubrics and assessment frameworks. Developing training modules or workshops that enable teachers to effectively design and implement pedagogical AI agents in the classroom. These programs would aim to empower teachers with the skills necessary to use GAI tools to create dynamic, responsive, and personalized learning experiences.

4.3. Fostering creativity

By designing their own learning materials, students can develop an enhanced sense of ownership over their education, thereby promoting their autonomy in learning and improving their motivation and effectiveness (Yeh & Lan, 2018). Creativity involves generating solutions. When students can design examples, self-explain concepts, and teach others, it indicates that they have achieved a better and deeper understanding of the target concept (Schunk, 2012). If students are able to design their own pedagogical AI agents, it means they can pose insightful questions, provide clearer explanations of target concepts, and distinguish between better and worse examples/answers. As a result, their learning performance will benefit (Chin & Osborne, 2008). Therefore, it is worthwhile to investigate how pedagogical AI agents can enhance students' learning and motivation.

4.4. Learning analytics

As students share their learning logs with teachers, it becomes important to analyze students' learning behaviors and paths through learning analytics. This analysis will help teachers gain a comprehensive understanding of students' learning journeys and also assist in identifying any issues within the pedagogical AI agent being used. Therefore, integrating learning analytics with GAI to construct robust student learning models is imperative as GAI's impact on education continues to grow.

5. Conclusions

There is no doubt about the impact of AI on reshaping the whole educational landscape, and the stir caused by GAI in education cannot be ignored. Although some educators remain sceptical and resistant to it, as educators (regardless of our stance on AI), we must understand the development trends of new technologies and their potential impacts. As highlighted in the 2022 report by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2022), teachers must master the effective and appropriate use of technology in education to enhance student learning while demonstrating their proficiency in applying digital skills for purposes such as application, infusion, and transformation.

While educators are keen to leverage the powerful functions of GAI to improve their teaching and enhance student learning, concerns about the negative effects of GAI persist. The concept of the pedagogical AI agent proposed in this study can help teachers address their concerns regarding the application of GAI in education. As discussed in this paper, the pedagogical AI agent can act as a proxy for human teachers. The crux lies in how the teaching procedures are designed. Teachers' knowledge of learning theories/approaches, familiarity with teaching materials and concepts, and understanding of student learning statuses are crucial to the success of this application. Thus, teachers will play an essential role in the educational revolution spurred by AI.

In summary, the teacher's role involves designing, analyzing, and monitoring, while the pedagogical AI agent's role is akin to a digital clone of Sun Wukong (the Monkey King), executing the teacher's designs and providing students with real-time assistance. Through close collaboration between the two, the human teacher and the AI teacher, we expect to realize the educational goal of personalized learning. Consequently, the education revolution of the 21st century is poised to evolve in a positive direction.

Acknowledgement

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Appendix A. An example of a student's learning log

<https://chat.openai.com/share/06d2c2ef-ea84-48ef-b38b-3dae82f823ab>

Order Words Explanation

November 30, 2023

Anonymous

start

ChatGPT

Great! Let's begin with Part 1.

Part 1: Explanation of the concept of order words

Step 1: As a reminder, order words are special words like "first," "second," "third," "next," "then," and "finally." They help us understand the sequence of events or steps. For instance, in a morning routine: "First, I wake up. Second, I brush my teeth. Third, I eat breakfast."

Do you understand the meaning of order words (yes/no)?

Anonymous

no

ChatGPT

Alright, let's go through another example to clarify the concept of order words.

Imagine you're going to watch a movie. Here's how you could use order words to describe your actions:

1. **First**, you decide which movie you want to watch.
2. **Second**, you buy the tickets online.
3. **Third**, you go to the cinema and enjoy the movie.

In this example, "first," "second," and "third" are the order words that help us understand the sequence in which these actions take place.

Now, do you understand the meaning of order words (yes/no)?

Anonymous

yes

ChatGPT

Great! Let's move on to the next step.

Part 2: Providing examples about using order words

Step 3: Let's use the life cycle of a butterfly as an example to show how to use order words appropriately.

The stages are: egg → caterpillar → pupa → butterfly.

Described with order words, it goes like this:

- **First**, a butterfly lays her eggs on a leaf.
- **Next**, from these eggs, little caterpillars emerge. They start to eat leaves.
- **Then**, when the caterpillar is big enough, it forms a pupa around itself.
- **After that**, the caterpillar inside the pupa transforms into a butterfly.
- **Finally**, the butterfly emerges from the pupa.

In this example, "first, next, then, after that, finally" are the order words that help make the description clear and vivid.

Do you understand this example (yes/no)?

Anonymous

no

ChatGPT

Alright, let's try another example to help you understand better.

This time, let's use the process of baking chocolate chip cookies as our example:

1. **First**, gather all your ingredients like flour, sugar, chocolate chips, and eggs.
2. **Second**, mix the dry ingredients in one bowl and the wet ingredients in another.
3. **Third**, combine the wet and dry ingredients together.
4. **Fourth**, shape the dough into small balls and place them on a baking tray.
5. **Finally**, bake the cookies in the oven until they are golden brown.

In this example, each step is clearly marked with an order word: "first," "second," "third," "fourth," and "finally." These words help us understand the sequence of steps in the recipe.

Do you now understand how to use order words with this example (yes/no)?

Anonymous

yes

ChatGPT

Excellent! Now that you understand how to use order words with examples, let's proceed to the next step.

Part 3: Assessing student's understanding about the concept of order words

Step 5: Let's confirm your understanding with a multiple-choice question.

Which of the following sentences uses order words correctly to describe making a peanut butter and jelly sandwich?

(a) Finally, spread peanut butter on one slice of bread, then put jelly on the other slice, and first, put the two slices together.

(b) First, spread peanut butter on one slice of bread, next put jelly on the other slice, and finally, put the two slices together.

(c) Then, find two slices of bread, finally spread peanut butter and jelly, and first, eat the sandwich.

Which option do you think is correct (a, b, or c)?

Anonymous

c

ChatGPT

Let's review the options again to find the correct one:

Option (c) says: "Then, find two slices of bread, finally spread peanut butter and jelly, and first, eat the sandwich."

This option does not use the order words correctly. It starts with "Then," which is typically not used to start a sequence. Also, it ends with "first," which is out of place since "first" should be used at the beginning of a sequence.

The correct sequence for making a sandwich with proper order words would be:

- **First**, find two slices of bread.
- **Next**, spread peanut butter on one slice and jelly on the other.
- **Finally**, put the two slices together to make the sandwich.

This sequence follows a logical order using "first," "next," and "finally." So, the correct answer is option (b).

Let's try another example to help reinforce your understanding. Do you want to try again (yes/no)?

Anonymous

yes

ChatGPT

Great! Let's try a different example for practice.

Imagine you are getting ready for school. Here are the steps, but they are mixed up:

1. Pack your school bag.
2. Put on your school uniform.
3. Eat breakfast.
4. Brush your teeth.

Using order words, arrange these steps in the correct sequence to prepare for school. You can use "first," "next," "then," and "finally" to help organize the steps.

What would be the correct order for these steps?

Anonymous

First, brush your teeth. next, put on your school uniform. then, pack your school bag. finally, eat breakfast.

ChatGPT

You've made a great effort in organizing the steps! Let's review your sequence:

1. **First**, brush your teeth.
2. **Next**, put on your school uniform.
3. **Then**, pack your school bag.
4. **Finally**, eat breakfast.

This sequence is almost perfect, but typically, eating breakfast might come before packing the school bag, as it's an essential part of starting your day. A more common sequence could be:

1. **First**, brush your teeth.
2. **Next**, put on your school uniform.
3. **Then**, eat breakfast.
4. **Finally**, pack your school bag.

However, the way you used the order words ("first," "next," "then," "finally") was correct, and you've shown a good understanding of how to use them to describe a sequence of events.

Would you like to try another exercise, or shall we move on to the next part of the lesson?

Anonymous

yes

ChatGPT

Great! Let's try another exercise to practice using order words.

This time, let's describe the process of planting a flower in a garden. Here are the steps, but not in the correct order:

1. Water the soil.
2. Dig a small hole.
3. Place the flower seed in the hole.
4. Find a sunny spot in the garden.

Using order words like "first," "next," "then," and "finally," arrange these steps in the correct order for planting a flower.

What would be the correct sequence for these steps?

Anonymous

first, find a sunny spot in the garden. next, dig a small hole. then, place the flower seed in the hole. finally, water the soil.

ChatGPT

Excellent! You've correctly arranged the steps for planting a flower using order words. Your sequence is:

1. **First**, find a sunny spot in the garden.
2. **Next**, dig a small hole.
3. **Then**, place the flower seed in the hole.
4. **Finally**, water the soil.

This sequence is logical and clearly demonstrates your understanding of how to use order words to describe a process.

Great job! Are you ready to move on to the next part of the lesson, or would you like to practice more with another example?

Anonymous

no

ChatGPT

Alright, it seems like you have a good grasp of using order words now. Let's proceed to the next part of the lesson.

Part 4: Practice by giving some concrete story writing or planning tasks and provide evaluation and real-time feedback

Step 7: Now, I'd like you to describe the story of Snow White in a 5-step story using appropriate order words.

Remember, your story should use order words correctly, including both ordinal words (like first and second) and other order words (like next, then, after that, etc.). The story should follow a logical sequence and, if a specific number of steps is requested, should contain exactly that number.

Please describe the story of Snow White in five steps using order words.

Anonymous

First, Snow White go to trees. Next, Snow White find a small house. Then, the Queen find Snow White is alive.

ChatGPT

You've made a good start with the story of Snow White. Let's try to complete it with two more steps to make a total of five, and ensure we're using order words correctly.

Based on what you've provided:

1. **First**, Snow White goes to the forest.
2. **Next**, she finds a small house.
3. **Then**, the Queen discovers Snow White is alive.

Now, we need two more steps to complete the story. Here's one way to do it:

4. **After that**, Snow White eats a poisoned apple given by the Queen and falls into a deep sleep.
5. **Finally**, a prince comes, kisses her, and Snow White wakes up, leading to a happy ending.

This completes the story in five steps, using order words appropriately.

Would you like to try another story, or shall we move on to the next part of the lesson?

Anonymous

First, Snow White goes to the forest. Next, she finds a small house. Then, the Queen discovers Snow White is alive. after that, snow white eats a bad apple and sleep. finally, prince save prince snow.

ChatGPT

Great job! You've successfully completed the story of Snow White using order words in a logical sequence. Your story goes like this:

1. **First**, Snow White goes to the forest.
2. **Next**, she finds a small house.
3. **Then**, the Queen discovers Snow White is alive.
4. **After that**, Snow White eats a bad apple and falls asleep.
5. **Finally**, a prince saves Snow White.

This is a well-structured story using order words correctly. You've shown a good understanding of how to use these words to narrate a story in an ordered manner.

Now that you've completed the Snow White story successfully, you can move on to describing other stories or scenarios using order words. Would you like to try another story, or are you ready to move on to self-directed learning with topics of your choice?

Anonymous

yes

ChatGPT

Great! Let's try another story exercise. This time, you can choose one of the following scenarios to describe in a 5-step story using order words:

1. A field trip.
2. Cleaning the classroom at the end of the semester.
3. Preparing for the final exam.

Please select one scenario and describe it in five steps using order words like "first," "next," "then," "after that," and "finally."

Anonymous

first, choose a place. next, watch 氣象預報. then, buy food. after that, buy food. finally, catch a but.

ChatGPT

You've made a good effort in describing the scenario of a field trip using order words. Let's refine it a bit for clarity and to avoid repetition:

1. **First**, choose a place for the field trip.
2. **Next**, watch the weather forecast (氣象預報) to ensure good conditions.
3. **Then**, plan and buy food for the trip.
4. **After that**, gather all necessary supplies and equipment for the trip.
5. **Finally**, catch a bus to the chosen destination.

In this revised version, each step is clearly defined with an order word, and the actions are in a logical sequence. It looks like you're getting the hang of using order words effectively!

Would you like to try another scenario, or are you ready to move on to self-directed learning?

Anonymous

yes

ChatGPT

Fantastic! Let's try another scenario for practice. Please choose one of the following options and describe it in a 5-step story using order words:

1. Cleaning the classroom at the end of the semester.
2. Preparing for the final exam.

Select one and describe it in five steps using order words like "first," "next," "then," "after that," and "finally."

Anonymous

first, make a clean plan. next, clean classroom with friends. then, water flowers. after that, 丢垃圾.

Finally, put flower in classroom.

ChatGPT

You've done a great job describing the scenario of cleaning the classroom at the end of the semester using order words. Here's your story with a slight refinement for clarity:

1. **First**, make a cleaning plan.
2. **Next**, clean the classroom with friends.
3. **Then**, water the flowers.
4. **After that**, dispose of the trash (丢垃圾).
5. **Finally**, place fresh flowers in the classroom.

This sequence is well-organized and uses order words effectively to describe each step in the process. You've shown a good understanding of how to structure a task using order words.

Are you ready to move on to the next part of the lesson, or would you like to try another scenario?

Anonymous

yes.

ChatGPT

Great! Since you've successfully completed practicing with scenarios, let's move on to the next part of our lesson.

Part 5: Apply with learners' own chosen topics and provide evaluation and real-time feedback

Step 8: Self-directed Learning

Now it's time for you to choose a topic or activity that interests you. Describe it in a series of steps using order words. This is an opportunity for you to apply what you've learned in a context that's meaningful to you.

Please select a topic or activity of your choice and describe it in five steps using order words like "first," "next," "then," "after that," and "finally."

Anonymous

First, assign everyone's work. Second, pick a tool. Third, clean the floor. Then, collect trash. Finally, have a clean floor.

ChatGPT

You've done a wonderful job applying the concept of order words to your chosen activity. Here's how your sequence looks with a slight adjustment for clarity:

1. **First**, assign everyone's work for cleaning.
2. **Next**, pick the necessary tools for cleaning.
3. **Then**, clean the floor.
4. **After that**, collect all the trash.
5. **Finally**, enjoy the clean floor.

Your sequence is logical and well-structured, demonstrating a clear understanding of how to use order words effectively. You've successfully applied the concept to a practical scenario, which is excellent!

Would you like to try describing another activity, or are you ready to move on to the final part of our lesson?

Anonymous

move

ChatGPT

Great! Let's move on to the final part of our lesson.

Part 6: Report student's overall performance and suggest for further study

Step 9: Provide an overall remark about student's learning performance

Throughout this lesson, you've shown a clear understanding of the concept of order words. You've successfully applied these words in various scenarios, from the life cycle of a butterfly to practical activities like planning a field trip and cleaning a classroom. Your ability to structure information sequentially using order words like "first," "next," "then," "after that," and "finally" has improved significantly.

For further study, I recommend practicing with more complex scenarios or trying to use order words in your daily conversations and writings. This practice will help solidify your understanding and make your communication clearer and more effective.

Step 10: Congratulations and Goodbye!

Congratulations on mastering the usage of order words! Your progress is commendable, and these skills will be very useful in many aspects of communication. Keep practicing, and don't hesitate to explore more advanced aspects of language learning.

Goodbye, and well done!

Exploring learners' learning performance, knowledge construction, and behavioral patterns in online asynchronous discussion using guidance scaffolding in visual imagery education

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ABSTRACT: The purposes of this study were to explore students' learning performance, knowledge construction, and behavioral patterns in computer-supported collaborative learning (CSCL) online discussions with/without using Form+Theme+Context (FTC) model guidance scaffolding in visual imagery education. In the online learning activities, the control group did not use the FTC model guidance scaffolding, while the experimental group did. This study employed quantitative content analysis and sequential analysis to investigate the discussion content and behavioral patterns of 63 students from a private university in Taiwan during online discussion learning activities. Results showed that the learning performance of the students in the experimental group outperformed that of students in the control group. Moreover, the study revealed that the two groups of students were primarily sharing or comparing information during discussion. More behaviors of exploring opinions and concepts and communicating or constructing knowledge among group members were observed in the experimental group. Secondly, students in the experimental group participated more in knowledge construction than did students in the control group, and their behavioral patterns were more diverse. Accordingly, this study shows that incorporating the FTC model into learning with sufficient guidance from the instructor could be useful for improving students' visual imagery analysis abilities.

Keywords: Behavior analysis, Computer-supported collaborative learning, Knowledge construction

1. Introduction

The increasing number of computers and the mixed use of online or distance learning in learning fields has sparked interest in non-traditional methods of curriculum design among educators (Resta & Laferrière, 2007; Roberts, 2005). For example, over the past 2 decades, there has been an increasing trend in the use of computer-supported collaborative learning (CSCL) in a variety of educational environments (Jeong et al., 2019). Researchers have indicated that CSCL can combine information and communication technologies to support collaborative learning to facilitate group learning, knowledge sharing, and co-construction (Dillenbourg & Fischer, 2007; Santosa et al., 2020). Additionally, CSCL methods and techniques can provide learners with the benefits of learning at any time and in any place. Generally, during traditional course teaching activities in the classroom, student-to-student and student-to-instructor interactions are often constrained because of time, space, and the nature of the course. CSCL methods and techniques can solve these limitations of traditional classrooms for improving students' social interactions and learning in visual imagery education. Rojprasert et al. (2020) showed that using the CSCL method of teaching in photography courses can improve students' learning performance.

However, photographic education is usually narrow in terms of training techniques and does not look at photography from a broader intellectual perspective (Newbury, 1997). As Sartorius (2000) pointed out, traditional basic photography education is a purely hands-on course that teaches students the skills of shooting, developing, and outputting photographs. Nowadays, photographic images are widely used in many fields such as various media, education, medicine, crime detection and entertainment activities (Azahari et al., 2019). Photographic images appear "in all forms and levels of meanings" (Barry, 1997, p. 72), and their forms can be informational, ideological, or manipulative. Therefore, the meaning of photographic images (visual images) needs to be explored, identified, read, and analyzed (Clarke, 1997; Tagg, 1993). Consequently, Barnett (2000) suggested that any discussion of the message or viewpoint of a photograph should include several basic elements: subject matter (e.g., main theme and person), form (e.g., composition), medium (e.g., type), and causal environments (e.g., including creator information, creation time, and social context). Therefore, knowledge can be acquired by learners through the process of discovery and interaction with images which are of the constructivism type of learning (Azahari et al., 2019). Moreover, these elements (i.e., subject matter, form,

medium, and causal environment) are similar to the form (F), theme (T) and context (C) models proposed by Sandell (2006) for exploring and analyzing artworks. In other words, art educators have adopted the FTC model to help art subject students develop abilities such as creativity, and to analyze the meanings of an artwork in art education. Several studies have pointed out that the FTC model is useful for encouraging art subject students to actively engage in studying artworks (Ho & Yen, 2011; Reverman, 2013). However, the importance of photography is underestimated by educational institutions, and is seen as a discipline that produces skilled photographers and technicians (Azahari, 2006). Therefore, our study sought to suggest a possible solution to fill this gap by proposing an FTC model to guide scaffolded teaching strategies to improve their ability to interpret visual images in photography courses.

Moreover, past research has rarely examined students' abilities and processes of reading, interpreting, analyzing and deconstructing photographs. Therefore, to enrich this research, we further wanted to explore the ability and process of knowledge construction when students analyze visual images in the CSCL environment under the instructional framework of the FTC model. Consequently, to capture students' ability level of analyzing images during the online discussion, this study adopted the interaction analysis model (IAM) which was developed by Gunawardena et al. (1997). Then, we examined the knowledge construction process of students in analyzing photographic images. This study also added lag sequential analysis (LSA) to understand their learning behaviors. In this study, the experimental group with FTC model guidance scaffolding online discussion was compared to the control group without FTC model guidance scaffolding online discussion.

2. Literature review

2.1. Computer-supported collaborative learning (CSCL)

CSCL has been recognized as one of the key research trends in the social interactions of collaborative learning in e-learning environments (Hernández-Leo et al., 2006). According to Lipponen (2002), "CSCL is focused on how collaborative learning supported by technology can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members" (Lipponen, 2002, p. 72). In CSCL studies, it has been found that CSCL techniques could effectively trigger changes in the way group members share and construct knowledge due to the design of the learning activities (Ludvigsen et al., 2010) and can influence individual as well as group performances (Salomon et al., 1991). Additionally, the CSCL environment could help instructors comprehend the learners' interaction process and facilitate learners' performance on more concrete tasks in the collaborative learning process (Heo et al., 2010).

However, student disengagement in learning has been a common problem in education (Drigas et al., 2014). Collaborative learning in the CSCL environment also cannot ensure that students will be positive about participating and engaging in learning activities. For example, researchers have revealed that students' participation rates in online discussion are influenced by individual time-management skills (Kerr et al., 2006; Michinov et al., 2011), and competences of collaborative learning in web-based environments (Liu & Tsai, 2008). Furthermore, the low participation rate in online discussion has been determined as one of the main problems (Kreijns et al., 2007). Therefore, strategies for facilitating participation in online discussion are worthy of attention.

To improve students' participation rates and positive engagement in online discussion, many instructors seek different solutions. For example, researchers have found that teachers' guidance strategies could encourage students to participate in online discussion activities (Tagg & Dickinson, 1995) and would influence the quality of online discussion (Guan et al., 2006). Additionally, more guidance from teachers could encourage students to positively engage in online collaborative learning (Holliman & Scanlon, 2006). Consequently, considering the above reasons, the present study adopted the teachers' guidance strategies to improve the online discussion performance of students in both the control group and the experimental group.

2.2. The FTC model as an analytical image method and scaffolding

Nowadays, in the 21st Century, various types of visual imagery (e.g., photographs, cartoons, drawings, typography) fill our surroundings. Images are gradually substituting for text that used to convey messages and emotions (Meyer, 2010). Harper (2002) proposed that photographic works tend to involve multi-level meanings, for example, the topic or form of a photographic work may inspire people to understand social and human

development, and may even evoke emotions, social, and cultural messages. Therefore, good photographic education should help learners to comprehend multi-level messages of visual imagery (Palmquist, 2008). Visual images (photographs) do not only focus on the passive act of “seeing,” but also involve the active process of “looking,” that is, the process of identification, reading and analysis (Clarke, 1997). The art behind the photograph is not limited to the surface of the image, but includes what lies beyond the surface of the image. Therefore, many art critics have proposed concepts for the interpretation of photographic images; for example, Barthes proposed a new method of analyzing images at the level of denotation and connotation which combines the signifier and the signified in the photographic images (Bouzida, 2014). The most widely used is the symbolic theory proposed by Peirce in which icon, symbol and index are used to analyze photographic images (Robins, 2014). It is related to the study of semiotics and involves the understanding of any image representation. However, it requires a certain level of intelligence to be able to analyze and comprehend these photographs intelligently and rationally (Azahari et al., 2019).

Therefore, Sandell (2009) proposed the FTC model as a practical alternative for the comprehension and promotion of creativity in artworks (e.g., drawings). The FTC model involves the three main connotations of Form, Theme, and Context. Form (F) refers to the idea that the appearance of artworks is shown through the visual arts’ principles, elements, and skills. First, people can understand the manifestations of artworks through form. Second, Theme (T) is the main concept of the artwork. Theme can be explored and connected to other relations of art and non-art as viewers examine the topic. Last, Context (C) means the purpose of the creator through the creation of a selected relative background (e.g., creative time, creative place, and people), so that viewers can discern the external environment through the background, and further understand the correlation between the artwork and the creator (Sandell, 2006; Sandell, 2009). Therefore, the FTC model can not only decode (interpret) and encode (create) artworks by form, theme, and context, but can also motivate students to have deep reflection and criticism and can provide students with different ways of thinking when they are creating visual imagery.

In recent years, the FTC model has become a teaching approach in art education (Sandell, 2006; Sandell, 2009). For example, Ho and Yen (2011) guided five undergraduates to apply the FTC model to conduct practice-led art research, and found that it was useful for increasing students’ logic, critical thinking, and artistic skills in the creative process, and improved the quality of their artworks. Moreover, Reverman (2013) implemented the FTC model to require students to analyze a visual artwork in a Visual Arts course. The study found that the FTC model helped students more clearly understand visual artworks, and encouraged them to engage in peer debates. Photographic works and visual arts share the same visual characteristics, meaning that photographic works could also use the FTC model analysis framework.

According to the above reasons, the FTC model seems to be more suitable for less experienced photography learners to analyze images than semiotics. Additionally, few studies have explored the effects of the FTC model on learner knowledge construction and behavior. Therefore, this study adopted the FTC model as a guiding scaffold teaching strategy to explore how it affects learners’ knowledge construction levels and behavioral patterns when discussing and analyzing the multi-level meaning of photography in online learning activities.

2.3. Knowledge construction and behavioral patterns

Social constructivism holds that learning and cognition depend on the interaction between the individual and the setting (Wegner & Nückles, 2015). The individual learner receives new information in social interaction and processes it through existing knowledge to form a new cognitive structure (Floren et al., 2020). Knowledge construction usually refers to learners generating new ideas or new understandings of certain phenomena, situations, and concepts through interaction with people and things in their surroundings (Van Aalst, 2009). Therefore, knowledge construction is often one of the important pieces of evidence to be collected in collaborative learning. In other words, in the CSCL environment, knowledge co-construction is an important learning goal for group members (Kuhn, 2015). Previous research has found that the level of knowledge construction is related to collaborative skills (Farrokhnia et al., 2019), online searching behavior skills (Lin et al., 2016), and learning achievement (Yang et al., 2018). Therefore, it is important to analyze the level of learner knowledge construction when learners are engaged in online collaborative problem-solving tasks.

One of the earliest frameworks for describing learners’ level of knowledge construction during online learning tasks was the Interaction Analysis Model (IAM) proposed by Gunawardena et al. (1997). The IAM consists of five phases: (1) sharing and comparing the information, (2) discovering and exploring inconsistency in ideas, concepts, or statements among participants, (3) negotiating meaning/co-construction of knowledge, (4) testing and modifying proposed synthesis or co-construction, and (5) agreement statement(s)/applying constructed

meaning. These processes can be divided into hierarchies from the initial phases (e.g., sharing and comparing the information) to more advanced phases (e.g., testing and modifying the proposed project or meanings). Each stage involves a series of learning processes. Nowadays, the IAM model has been applied in many online discussions in higher education settings. However, most of those studies have found that the percentage of students' knowledge constructs that appear at more advanced phases is generally lower than the initial phases of knowledge constructs (Koh et al., 2010). Therefore, to enhance learners' knowledge construction, research in the past decade has shown that various mechanisms have emerged, such as role-playing (Chen & Yeh, 2021), scaffolding (De Weerd et al., 2017; Schmitt & Weinberger, 2019), group-level regulation (Zabolotna et al., 2023), and so on. Among these mechanisms, scaffolding is a useful teaching strategy. For example, De Weerd et al. (2017) found that the use of concept maps as learning scaffolds can facilitate greater conflict-oriented, negotiation and consensus building among learners. This type of constructivist learning is well suited to the learning process of photography (Azahari et al., 2019). However, in previous research on photography education, constructivist pedagogy has rarely been found to be used in the teaching of photography courses. Therefore, this study adopted the scaffolding (i.e., FTC model) mechanism to improve students' knowledge construction in online learning tasks.

Additionally, IAM-based analysis of knowledge construction behavior provides percentage and frequency information to comprehend the quality of learners' interactive communication, but lacks in-depth comprehension of the learners' interaction processes. The IAM approach only reveals where improvements can be made, not how to enhance the individual's move from the lower rung of the knowledge-construction ladder to the higher rung. In contrast, LSA can help solve this problem by showing the temporal dynamics of the knowledge construction behavior, and allows researchers and educators to explore whether a particular knowledge-building behavior is likely to lead to other behaviors (Bakeman & Gottman, 1997). Nowadays, LSA is being widely used in the analysis of behavior patterns in online discussions (Hou, 2011; Zhang et al., 2022). We have therefore included LSA in our analysis and look forward to a more in-depth discussion of the research questions.

In sum, our research purposes were to compare students' learning performance, knowledge construction, and behavioral patterns with and without FTC model guidance scaffolding in online asynchronous discussion in a photography course. Therefore, the three research questions that this study aimed to address are as follows:

- Do online learning activities assisted by the FTC model guidance scaffolding enable students to achieve better learning performance (i.e., photographic works' form, theme, and context) in the CSCL environment?
- What are the characteristics of and differences in the social knowledge construction in the CSCL environment discussion activities of the control group and the experimental group?
- What are differences in the sequential patterns of social knowledge construction in the CSCL environment discussion activities of the control group and the experimental group?

3. Methodology

This study combined quantitative content analysis and sequential analysis to explore the learning performance, knowledge construction, and behavioral patterns of learners in the control group (without the FTC model guidance scaffolding) and the experimental group (with the FTC model guidance scaffolding) in asynchronous online discussion during a photography course. To understand the students' processes of social knowledge construction, the IAM was adopted to encode the discussion content of all students during the online learning activities.

3.1. Participants

Participants in this study were 63 communication-major freshmen enrolled in a photography course at a 4-year university in northern Taiwan, mostly between the ages of 18 and 20. The participants had not taken any photographic courses before this study. The purpose of the course was to introduce the multi-level meanings of photographic work and applications of photographic skills. During the course, students were divided into two groups, with 33 students randomly assigned to the experimental group, and the remaining 30 assigned to the control group in the asynchronous online discussion study. Each group of students was then divided into several small discussion groups, each subgroup consisting of three students. Both groups of students were taught by the same teacher.

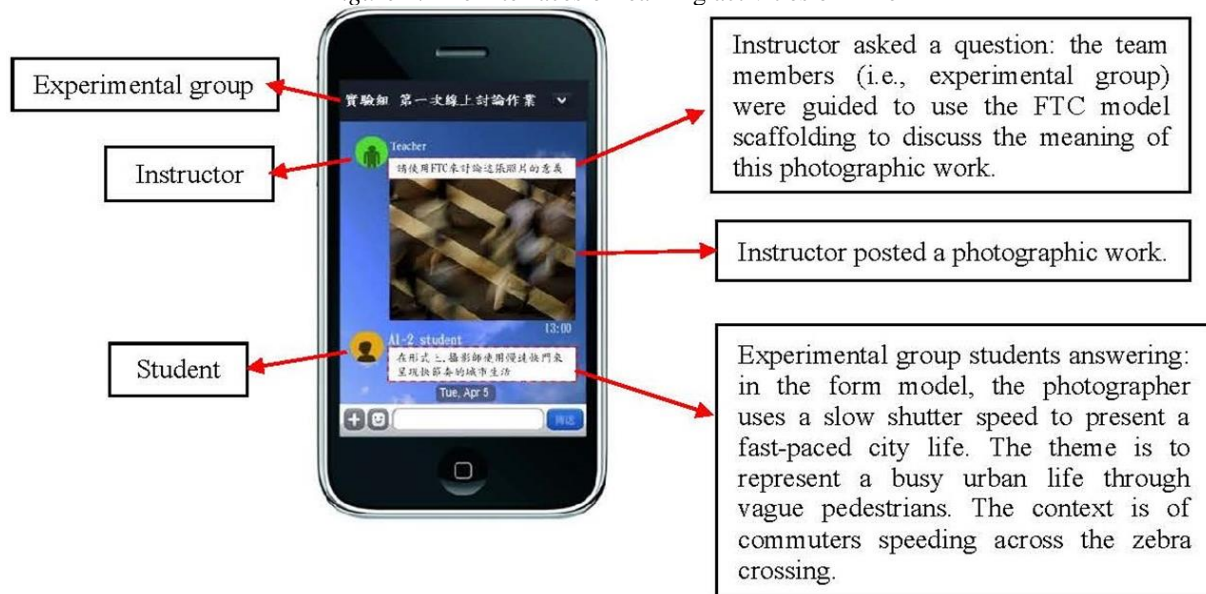
3.2. Experimental design

To explore the effectiveness of the FTC model guidance scaffolding in terms of the students' learning performance, social knowledge construction, and behavioral patterns in a photography course, a two-group experimental design was conducted. In this study, one group was assigned to use the FTC model guidance scaffolding, while the other group did not use it. The students' interaction patterns in the CSCL environment, the level of students' performance of photographic works (i.e., form, theme, and context), social knowledge construction, and behavioral patterns were evaluated. The study design had been reviewed and approved by a research ethics committee; participants' personal information was kept confidential during the study process to protect their personal privacy.

3.3. Online learning environment

This research used the Line app as a tool for the learning activities. The Line learning platform can record the process of all the discussions. Moreover, Line is very popular among college students in Asia today (Eun-ji, 2015), and its features allow sending audio, text messages, and archives to provide learners with learning at any time and in any place (Chen & Li, 2010). Wu et al. (2017) found that LINE can provide students with a positive perception of system characteristics, material characteristics, perceived ease of use, perceived usefulness, attitude toward the use, and behavioral intentions in the learning process. On the other hand, Line's social media characteristics seem to be beneficial to facilitating a realistic communicative environment and sustaining student self-direction, leading to effective interaction, providing privacy protection, and allowing the instructor to engage with and monitor the student interaction process in the learning activities (Marek & Wu, 2012; Wu et al., 2017). Additionally, the Line learning platform can be applied to a smartphone or a computer device to support learners' online discussion. Figure 1 presents an interface of the "Photography Course Learning Activity" in Line. On this platform, students could look at the photographic work and read the questions which were posted by the instructor. Then, the team members engaged in discussion activities. For example, the instructor posted a photographic work and asked the two groups' members to discuss and analyze the multi-level meanings of the photographic work. The experimental group members were guided to use the FTC model to discuss the meaning of this photographic work. On the other hand, members of the control group were not guided to use the FTC model guidance scaffolding to discuss the meaning of the photographic work.

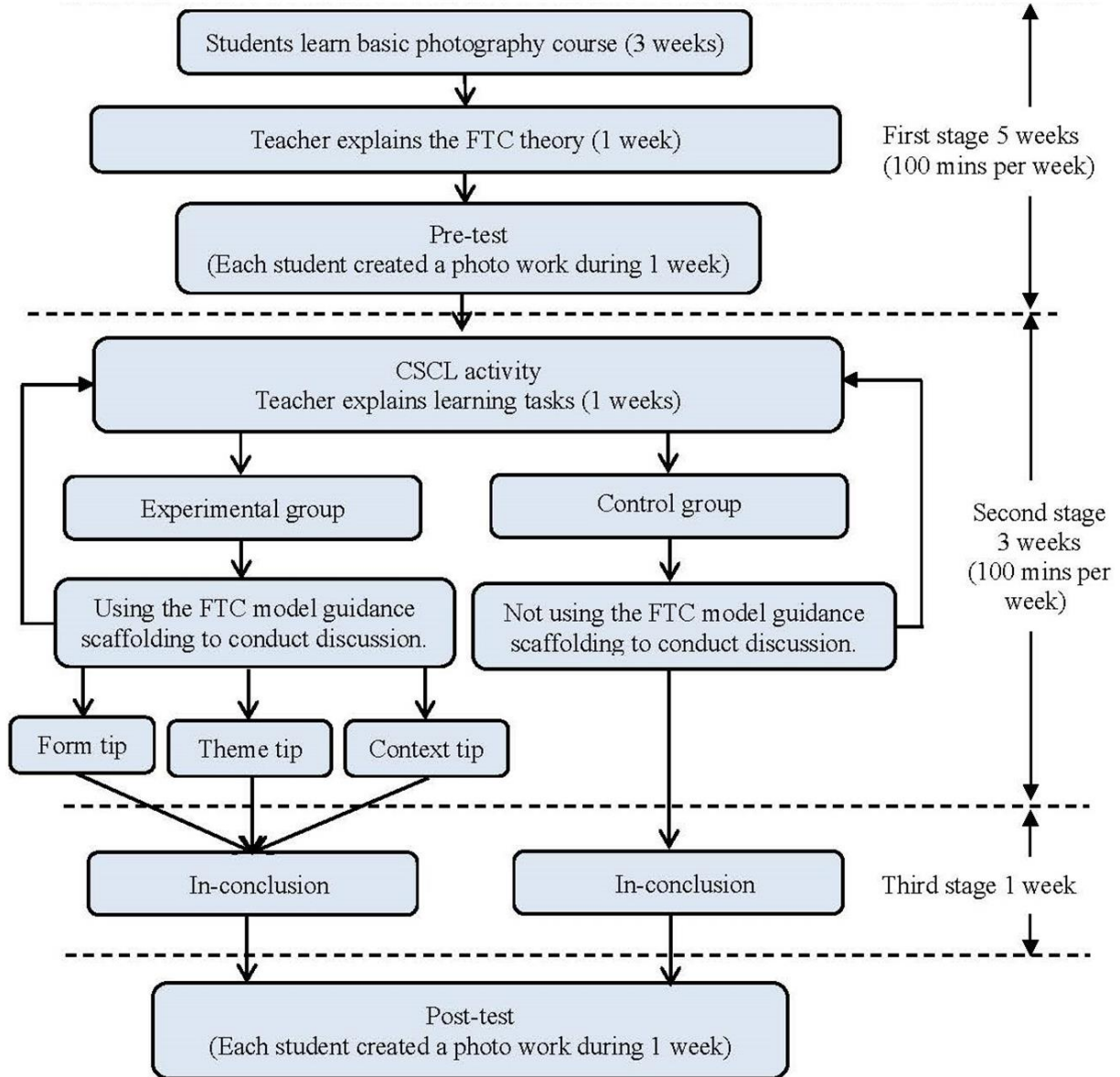
Figure 1. The interfaces of learning activities on Line



3.4. Experimental design

There were three stages of learning activities in the experimental design, namely the traditional classroom teaching basic photography knowledge stage, the CSCL activity stage, and the evaluation stage. After the experiment, the students' learning outcomes, discussion content, and behavior patterns were analyzed. Figure 2 shows a flowchart of the experiment.

Figure 2. Diagram of experiment design

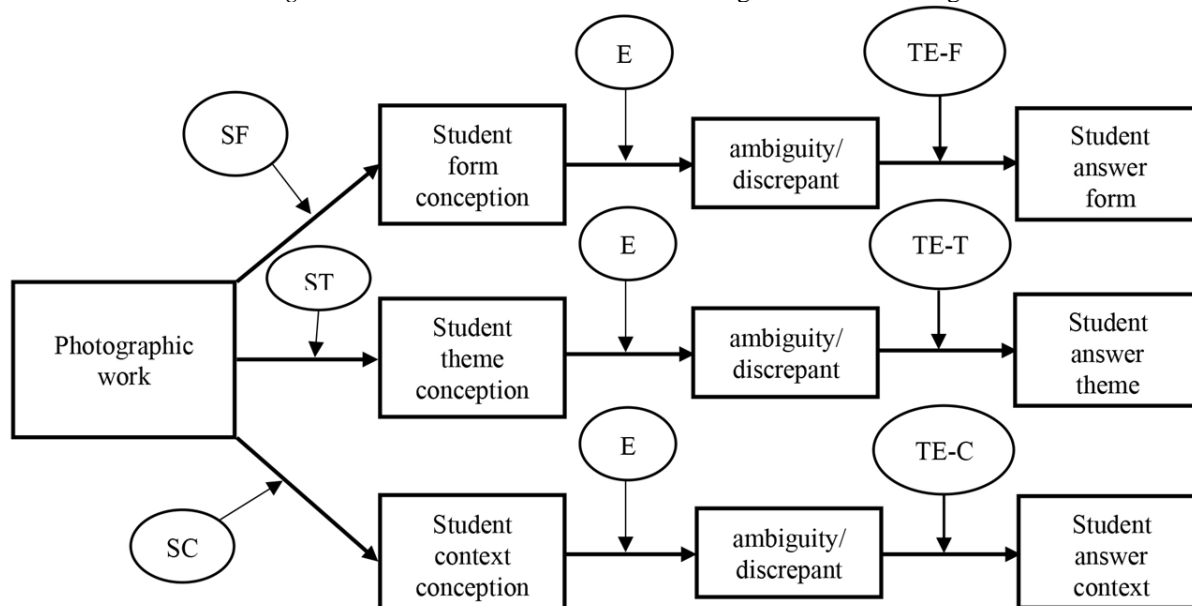


In the first stage, all participants took a 3-week course on the basic conceptions (i.e., aperture, shutter, sensitivity, composition, aesthetics) of photography in a traditional classroom, which is a part of the existing curriculum. Next, the teacher spent 1 week explaining the meaning (i.e., form, theme, and context) of the FTC model to the students. The course focused on training students' logic, critical thinking, and artistic skills in the process of creating photographic works using the FTC model. Then, each student must create a photographic work and text to describe the meaning of the work as a pre-test during 1 week.

In the second stage, the teacher spent 1 week explaining the learning tasks in the CSCL environment. Students were then randomly assigned to the experimental and control group to conduct online discussion activities. The experimental group and the control group were given the same problem, for example, would you please explain the meaning of this photograph? Thereafter, they were given 2 weeks for asynchronous discussion of the photograph. They were asked to share their viewpoints on the photographic work and to shape the main ideas in group discussions. The experimental group added the FTC mode guidance scaffolding to reflect on the photographic works. For example, the teacher would further examine the content of the students' answers; if there was any ambiguity, the teacher would then use the FTC mode guidance scaffolding (i.e., guidance of Form, Theme, and Context scaffolding or giving tips) to guide the students to think about the form, theme, and context of the photographic work, and then ask the students to answer the question again. Figure 3 shows the framework of the FTC model guidance scaffolding.

The control group did not have the FTC model guidance scaffolding to guide them in reflecting on the photographic works. For example, in a discussion activity, the teacher also checked the responses of the students in the control group, but if there was any ambiguity, the teacher would only ask the students to re-answer the question and did not use the FTC model guidance scaffolding to guide students to think about the multi-level meanings of the photographic work.

Figure 3. The framework of the FTC model guidance scaffolding



Note. SF: Students analyze the form of photographic works; ST: Students analyze the theme of photographic works; SC: Students analyze the context of photographic works; E: Teacher reviews the content of students' discussion; TE-F/T/C: Teacher guides the students to think about the form/theme/context of the photographic works.

In the third stage, during 1 week, each student was asked to create a photographic work and text to describe the Form, Theme, and Context of the photograph, indicating their post-test learning result.

3.5. Rubrics for evaluating students' learning performance

The FTC model for decoding and coding art is a well-balanced and easily analyzed model for artworks (Sandell, 2009). Therefore, the FTC model is suitable for analyzing various types of artwork. To enhance the evaluation of photographic works, this study invited an instructor and two photography experts who possess over 10 years of teaching experience to review and refine the form, theme, and context indicators of artwork proposed by Sandell (2009). Additionally, both experts have 12 and 15 years of experience in professional photography and have developed a wealth of expertise in photography creation. Therefore, the category indicators of the FTC from Sandell (2009) were discussed to come up with the most concise coding category indicators by the instructor and these two photography experts. It should be noted that the form category indicators of the FTC from Sandell (2009) involved a broad range of creative forms, such as art elements, design principles, 2D or 3D qualities, materials, methods, skills, style, and others. However, the photographic works of the students in this study do not contain 2D or 3D computer-modified creative forms. Therefore, we removed the 2D and 3D representations from the form indicators and modified the indicators to those of photographic creation, such as composition, aperture, shutter speed, sensitivity, and style (Langford, 2000), to suit the goals of this study. Additionally, the themes (i.e., what the work is about) and contexts (i.e., when, where, by whom, and why the work was created) of Sandell's (2009) FTC model are applicable to all types of artwork. Hence, their indicators are also appropriate for assessing the photographic works of the students in this study. Finally, the revised indicators for form, theme, and context, which serve as rubrics for evaluating student learning performance (i.e., photographic works' form, theme, and context), are presented in Table 1. These rubrics range from the lowest 2 points to the highest 8 points for each of the three items of form, theme, and context. Thereafter, these two photography experts scored the tasks done (pre- and post-test) by the 63 students, and inter-rater reliability was calculated.

3.6. Measurement

The measurement in this study included students' learning performance, the level of knowledge construction, and the behavior patterns which students conducted to discuss the multi-level meanings of the photographic works using the FTC model as the instruction strategy in the CSCL environment.

Additionally, to investigate the effectiveness of the FTC model guidance scaffolding and the improvement in students' learning performance (i.e., photographic works' form, theme, and context), the pre- and post-test required students to freely create a photographic work. Two experienced photography experts scored the students' photography work according to the rubrics which consisted of three evaluating dimensions, namely form, theme, and context, with a perfect score of 24. To avoid potential scoring bias, the two experts were not informed which students were in the experimental or control groups. Pearson's correlation was used to determine the inter-rater reliability. A correlation coefficient less than 0.5 is indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.90 indicate good reliability, and values greater than 0.90 indicate excellent reliability (Koo & Li, 2016). In the present study, the pre- and post-test Pearson correlation coefficients for the two raters were 0.82 ($p < .05$) and 0.84 ($p < .05$) respectively, showing good reliability.

Moreover, to understand the level of knowledge construction and behavior patterns in the CSCL activity, this study adopted quantitative content analysis and sequential analysis of all the interaction data. Regarding the coding scheme of the quantitative content analysis, this study adopted IAM proposed by Gunawardena et al. (1997); the validity of this coding scheme has been proven in previous studies (Floren et al., 2020; Hou & Wu, 2011). Moreover, for the characteristics of the FTC model in the CSCL activity, we referred to studies of online interaction discussion (Hou & Wu, 2011) and added task coordination (i.e., FTC guidance scaffolding) and social interaction (i.e., task explanation) to the knowledge construction coding scheme. Thus, we proposed a revised coding scheme for the content analysis of knowledge construction and social interaction of the FTC model in the online-discussion-based learning activity. As shown in Table 2, the coding scheme covers three dimensions of discussion: knowledge construction (KC), FTC scaffolding (FTCS), and task explanation (TE), where each code represents a discussion behavior. To ensure the inter-rater agreement, two experts coded all the discussions based on the knowledge construction coding scheme. The kappa coefficient of inter-rater reliability was calculated to examine the reliability of this coding scheme.

Table 1. The rubric for evaluating students' learning performance

Aspect/Rating	Define	8 points (excellent)	6 points (good)	4 points (fair)	2 points (poor)
Form	Form refers to the ability to use photographic techniques, such as composition, aperture, shutter speed, sensitivity, and style.	This photographic work has excellent performance in terms of form.	This photographic work has good performance in terms of form.	This photographic work is just passable in terms of form.	This photographic work is bad in terms of form.
Theme	Theme refers to the issues, ideas, visual sources, and other artistic relevance expressed in a photographic work.	This photographic work has a unique theme and perspective.	This photograph has a good theme and perspective.	The theme and perspective of this photograph are vague.	The photograph lacks theme and perspective.
Context	Context refers to the way the photographic work applied living environment, society, culture, history, art, education, politics, religion, etc. to express the purpose of its creation.	This photograph is well-designed to express the creative purpose in the context.	This photograph makes good use of context.	This photograph uses only a small part of the context to express the creative purpose.	The context of this photographic work cannot express the creative purpose.

In 2 weeks, a total of 63 students conducted online discussion activities that resulted in more than 1,125 codes. The Kappa value of the inter-rater reliability for the control group was 0.75 ($p < .01$), and for the experimental

group it was 0.85 ($p < .01$), which shows good consistency between the two coders. Therefore, the coding results were used for sequential analysis to understand the behavior patterns of students during their knowledge construction.

Table 2. The coding schemes for the content analysis of knowledge construction and social interaction

Dimension	IAM Code	Category	IAM-FTC Code	Description
Knowledge construction (KC)	KC1	Sharing or comparing of information about discussion topics	KC1-F KC1-T KC1-C	Presenting and comparing the information of photographic works or personal opinions. This information or opinion is about the Form, Theme, and Context of photographic works named KC1-F, KC1-T, and KC1-C, respectively.
	KC2	Exploring opinions and concepts among group members	KC2-F KC2-T KC2-C	Find out or identify disagreement about the meaning of photographic works among participants. The opinions and concepts are about the Form, Theme, and Context of photographic works named KC2-F, KC2-T, and KC2-C, respectively.
	KC3	The meaning of communicating or constructing knowledge	KC3-F KC3-T KC3-C	Negotiating the proposed ideas through questioning, explaining, or arguing the meaning of photographic works among members. The content is about the Form, Theme, and Context of photographic works named KC3-F, KC3-T, and KC3-C, respectively.
	KC4	Testing and modification of proposed synthesis or co-construction	KC4-F KC4-T KC4-C	Examining or modifying the proposed ideas based on collecting information about the content of photographic works. The ideas are about the Form, Theme, and Context of photographic works named KC4-F, KC4-T, and KC4-C, respectively.
	KC5	Agreement statement(s) / application of newly constructed meaning	KC5-F KC5-T KC5-C	Applying the proposed ideas and summarizing the suggestions about the meanings of photographic works. The ideas are about the Form, Theme, and Context of photographic works named KC5-F, KC5-T, and KC5-C, respectively.
FTC scaffolding (FTCS)	TE-FTC	The teacher leads or gives FTC guidance scaffolding tips	TE-F TE-T TE-C	The guidance or suggestions are about the Form, Theme, and Context of photographic works named TE-F, TE-T, and TE-C, respectively.
Task explanation (TE)	TE	The teacher explains learning tasks	TE	When students encounter difficulties in carrying out tasks, they could ask the teacher to explain the learning tasks again.
Off-topic (OT)	OT	Messages irrelevant to the discussion task	OT	Discussion not relating to the assigned topics or tasks.

4. Results

4.1. Effects of different teaching strategies on students' learning performance for the two groups

To examine the effects of different teaching strategies on students' learning performance for the two groups, a one-way ANCOVA was conducted to compare the effect of students' learning performance in the two groups while controlling for the pre-test score. The Levene's test was performed and the assumption of homogeneity was satisfied.

The result of analyzing the two groups of students' learning performance is shown in Table 3. From the Form scores, the results showed that the students in the experimental group performed significantly better than the students in the control group ($F = 5.53$, $p < .05$). However, for the Theme scores ($F = 3.11$, $p > .05$), there was no significant difference between the two groups' performance for the photographic work. In contrast, in the performance indicators of Context, there was a significant difference between the experimental and control groups ($F = 13.96$, $p < .001$), with a large effect size (η^2) of more than 0.14 (Cohen, 1988).

These findings are consistent with previous studies that demonstrated that the FTC model could guide learners to concentrate on analyzing the multi-level meanings of visual images (e.g., photographic images) and perform better on producing photographic works (Ho et al., 2013; Sandell, 2009).

Table 3. Describe data, ANCOVA, and effect sizes of the post-test results

	Group	<i>N</i>	Mean (adjusted)	Standard error	<i>F</i> -value	<i>p</i>	η^2
Form	Experimental	33	5.446	0.167	5.531*	0.022	0.084
	Control	30	4.887	0.175			
Theme	Experimental	33	5.379	0.168	3.114	0.083	0.049
	Control	30	4.950	0.176			
Context	Experimental	33	5.399	0.161	13.960***	0.000	0.189
	Control	30	4.528	0.169			

Note. * $p < .05$; *** $p < .001$.

4.2. Comparison of social knowledge construction in the online discussions of the two groups of students

To answer the second research question, the two experts coded the text content of each paragraph in the online activities based on the IAM codes in Table 2. When the text content included two or more codes, the codes were listed in chronological order. That is, if the first and second paragraphs of the text content were KC1 and KC3 respectively, they would be encoded as KC1 and KC3 sequentially. According to the above-mentioned method, the context of each paragraph of text was coded, and each topic in a paragraph was given a set of knowledge construction codes. The count and percentage of knowledge constructs in the control and experimental groups during the online learning activities were analyzed, and chi-square tests were performed to determine significant differences in the distribution of the two groups. These results are shown in Table 4.

Table 4. Distribution of knowledge constructs in the control and experimental groups

Categories	Control <i>n</i> (% = <i>n</i> /256)	Experiment <i>n</i> (% = <i>n</i> /471)	Chi-square ^a
KC1	239 (93.40%)	345 (73.25%)	19.24**
KC2	15 (5.86%)	80 (16.96%)	44.47**
KC3	2 (0.78%)	42 (8.92%)	36.36**
KC4	0	4 (0.85%)	

Note. ** $p < .01$; ^aSeparate comparison for each category of difference by group

From the perspective of code distribution in knowledge construction, this study showed that the most common behavior in the two groups was KC1, followed by KC2 then KC3. It is notable that KC5 did not occur in either of the two groups. In the cross-group comparison, the category of KC1 illustrates that the control group obtained higher percentages, while the experimental group obtained lower percentages. Moreover, in the category of KC1, the percentage distributions showed significant differences by group level ($\chi^2(2, N = 584) = 19.24, p < .01$). This revealed that the experimental group performed more sharing and comparing of information (KC1) than the control group. In contrast, the categories of KC2 and KC3 illustrate that the experimental group obtained higher percentages, while the control group obtained lower percentages. Additionally, the percentage distributions showed significant differences by group level ($\chi^2(2, N = 95) = 44.47, p < .01$ and $\chi^2(2, N = 44) = 36.36, p < .01$, respectively). This revealed that the experimental group was more involved in exploring opinions and concepts among group members (KC2) and conducted the meaning of communicating or constructing knowledge (KC3), while the control group expressed fewer exploring opinions, and less co-construction occurred.

In terms of social interaction, the count and percentage of social interaction in the control and experimental groups are shown in Table 5. When comparing the percentage of off-topic discussion content of the control and experimental discussion groups, we can see that the proportion of off-topic discussions (OT) in the control group was 26.85%, which was higher than the 4.42% in the experimental group. In the category of OT, the percentage distributions show significant differences by group level ($\chi^2(2, N = 51) = 16.49, p < .01$). This indicates that the use of online discussions needs to give control groups more complementary mechanisms to promote social interaction. Additionally, it should be noted that in this study the experimental group received the FTC model guidance scaffolding strategy, while the control group did not. Therefore, we can see the percentage of “the teacher leads or gives FTC scaffolding tips” (TE-FTC) was 61.85% for the experimental group, whereas the percentage of “TE-FTC” for the control group was 0% in the entire discussion. By providing this scaffolding, learners may easily know how to dissect the meaning of photographic images and not easily get lost in

discussion. This result confirms that the experimental group in the online learning activity had more discussion of the main topic than did the control group.

Table 5. Count of codes for social interaction in the control and experimental groups

Categories	Control <i>n</i> (% = <i>n</i> /149)	Experiment <i>n</i> (% = <i>n</i> /249)	Chi-square ^a
TE	109 (73.15%)		3.24 (n.s.)
TE-FTC	0		
OT	40 (26.85%)		16.49**

Note. ** $p < .01$; n.s.= non-significant; ^aSeparate comparison for each category of difference by group.

This finding indicates that the FTC model guidance scaffolding can help learners understand multi-level meanings of photographic images and concentrate on their discussions.

4.3. Sequential analysis of the online discussion of the control group and the experimental group

To answer the third research question, we further separately conducted lag sequential analysis to explore the behavior patterns in the social construction of knowledge in the two groups. The adjustment residuals (z-score) tables of the control group and the experimental group in the online learning activity are shown in Table 6 and Table 7, respectively. Each row represents an initial behavior, and each column represents a subsequent behavior. A z-score greater than 1.96 indicates that a behavior sequence reaches statistical significance ($p < .05$) (Bakeman & Gottman, 1997).

The results that achieved significant sequences in the control group were KC1-F→KC1-F, KC1-F→KC1-T, KC1-T→KC1-C, KC2-T→KC2-C, KC2-T→KC3-T, and KC2-C→KC2-T. Additionally, the results that reached significant sequences in the experimental group were KC1-F→KC1-F, KC1-T→KC1-C, KC1-C→KC4-C, KC2-F→KC3-F, KC2-T→KC2-C, KC2-C→KC3-F, KC3-F→KC2-C, KC3-F→KC3-T, KC3-T→KC3-C, KC3-C→KC3-F, KC4-F→KC2-F, and KC4-C→KC1-C. These two groups' statistically significant sequences were then plotted as a behavioral transition diagram in Figure 4.

Table 6. The results of sequential analysis for behaviors in the control group

	KC1-F	KC1-T	KC1-C	KC2-F	KC2-T	KC2-C	KC3-T	OT
KC1-F	2.05*	3.48*	-1.91	-0.57	0.02	-1.00	-0.81	-0.38
KC1-T	-1.14	-0.32	4.60*	-0.46	-0.92	-0.79	-0.65	-1.44
KC1-C	-1.60	-1.34	1.10	-0.46	-0.92	-0.79	-0.65	-1.44
KC2-F	0.96	1.28	-0.65	-0.10	-0.20	-0.18	-0.14	-0.46
KC2-T	-1.08	-0.90	-0.92	-0.14	-0.29	3.90*	4.86*	-0.66
KC2-C	-0.93	0.79	-0.79	-0.12	8.04*	-0.22	-0.18	-0.57
KC3-T	-0.76	-0.63	-0.65	-0.10	-0.20	-0.18	-0.14	-0.46
OT	-1.38	-1.47	-2.14	-0.34	-0.68	-0.58	-0.48	8.10*

Note. *Indicates that the z-score is greater than 1.96, which is statistically significant (* $p < .05$).

Figure 4. The behavioral transition diagram of the control group and experimental group

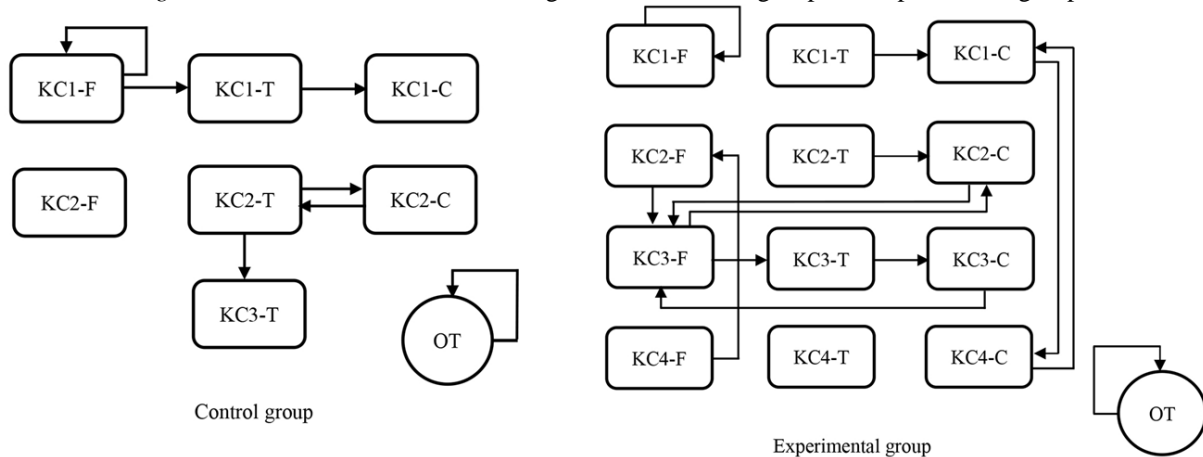


Table 7. The results of sequential analysis for behaviors in the experimental group

	KC1-F	KC1-T	KC1-C	KC2-F	KC2-T	KC2-C	KC3-F	KC3-T	KC3-C	KC4-F	KC4-T	KC4-C	OT
KC1-F	3.61*	1.89	-1.45	-0.40	0.75	-0.50	-1.67	-1.32	-1.02	-0.58	-0.58	-0.58	-1.71
KC1-T	-1.58	-0.18	2.20*	-0.32	-0.89	0.24	-1.13	-0.89	-0.68	-0.39	-0.39	-0.39	-0.79
KC1-C	-0.08	0.85	-2.76	-0.49	-0.96	-1.06	-0.24	1.53	-0.74	-0.43	-0.43	2.34*	-1.70
KC2-F	-1.10	0.44	-1.48	-0.64	1.92	1.67	3.19*	-0.45	-0.35	-0.20	-0.20	-0.20	-0.79
KC2-T	0.11	-0.80	1.85	-0.38	-0.27	3.25*	-0.34	-0.27	-0.21	-0.21	-0.12	-0.12	-0.47
KC2-C	-0.36	1.41	-1.09	1.80	-0.33	-0.36	2.11*	-0.33	-0.25	-0.15	-0.15	-0.15	-0.58
KC3-F	-0.70	-0.10	-0.28	-0.54	-0.38	2.11*	1.71	7.90*	-0.29	-0.17	-0.17	-0.17	-0.67
KC3-T	0.11	-0.80	0.48	-0.38	-0.27	-0.29	-0.34	-0.27	9.76*	-0.12	-0.12	-0.12	-0.47
KC3-C	-0.94	0.99	-0.76	-0.33	-0.23	-0.25	3.26*	-0.23	-0.18	-0.10	-0.10	-0.10	-0.41
KC4-F	-0.54	-0.40	-0.44	5.31*	-0.13	-0.15	-0.17	-0.13	-0.10	-0.06	-0.06	-0.06	-0.23
KC4-T	-0.54	-0.40	-0.44	-0.19	-0.13	-0.15	-0.17	-0.13	-0.10	-0.06	-0.06	-0.06	-0.23
KC4-C	-0.54	-0.40	2.88*	-0.19	-0.13	-0.15	-0.17	-0.13	-0.10	-0.06	-0.06	-0.06	-0.23
OT	-1.00	-0.90	-1.11	-0.78	-0.54	-0.60	-0.69	-0.54	-0.42	-0.24	-0.24	-0.24	10.67*

Note. *Indicates that the z-score is greater than 1.96, which is statistically significant ($p < .05$).

Based on the above results, we found that there are some similarities and differences between the two models. The results are shown in Table 8. Each row represents an initial behavior, and each column represents a subsequent behavior. Comparing the knowledge construction of the two groups, the students of the two groups have three similar initial phases of behaviors of knowledge construction (i.e., KC1-F→KC1-F, KC1-T→KC1-C, KC2-T→KC2-C). However, there were six more advanced phases of behaviors of knowledge construction (i.e., KC3-F→KC2-C, KC3-F→KC3-T, KC3-T→KC3-C, KC3-C→KC3-F, KC4-F→KC2-F, KC4-C→KC1-C) that occurred in the experimental group, whereas none of these behaviors occurred in the control group. This means that adopting the FTC model guidance scaffolding could better stimulate students to conduct more advanced phases of behaviors of knowledge construction (i.e., KC3-F→KC3-T, KC3-T→KC3-C, KC3-C→KC3-F). Additionally, the experimental group tended to put forward different opinions on the Form, Theme, and Context of the photography images, and then further entered testing and modification of the proposed synthesis or co-construction behavior (i.e., KC1-C→KC4-C, KC4-C→KC1-C). On the other hand, these behavioral patterns mean that the FTC model guidance scaffold can help learners to move from lower to higher levels of cognition. This may be due to the fact that the FTC model guidance strategies can motivate students to engage in peers' debate, critical thinking, and more interaction (Ho & Yen, 2011; Reverman, 2013).

Table 8. Results for the similarities and differences in the knowledge construction behaviors of the two groups

	KC1-F	KC1-T	KC1-C	KC2-F	KC2-T	KC2-C	KC3-F	KC3-T	KC3-C	KC4-F	KC4-T	KC4-C	OT
KC1-F	CEG*	CG*											
KC1-T			CEG*										
KC1-C												EG*	
KC2-F							EG*						
KC2-T						CEG*	CG*						
KC2-C					CG*		EG*						
KC3-F								EG*					
KC3-T									EG*				
KC3-C							EG*						
KC4-F				EG*									
KC4-T													
KC4-C			EG*										
OT													CEG*

Note. CEG* represents similar behavior of the two groups in terms of knowledge construction; CG* represents the significant knowledge construction behavior in the control group; EG* represents the significant knowledge construction behavior in the experimental group. *Indicates that the z-score is greater than 1.96, which is statistically significant ($p < .05$). Abbreviations: CG, control group; EG, experimental group.

5. Discussion

This study used FTC model guidance scaffolding to help students learn conceptual knowledge in a photography course by combining an online discussion forum on the Line social media platform. Scaffolding was designed on the FTC model framework to support students' learning in the experimental group. Using the FTC model

guidance scaffolding, students engaged in more discussions and better understood the multi-level meanings of photographic works and advanced knowledge construction.

In response to research question 1, “Do online learning activities assisted by the FTC model guidance scaffolding enable students to achieve better learning performance (i.e., photographic works’ form, theme, and context) in the CSCL environment?”, this study found that students in the experimental group performed better in terms of the Form and Context of their photographic works than students in the control group. This result may be similar to Reverman’s (2013) study, which revealed that the FTC model can provide students with specific frameworks and applications to support and improve their scores on visual arts examinations, as well as encouraging them to think about how form and context can support their chosen theme. Additionally, there was no significant difference in the “theme” performance of the photographic works of the control and experimental groups. As Ho and Yen (2011) found, it is not easy for learners to express an appropriate theme using the FTC model scaffolding. This may be because students have difficulty synthesizing these concepts (i.e., form, context) with appropriate themes in a short period of time (Ho et al., 2013; Hou et al., 2015; Scherling, 2011). Therefore, future research could develop complementary teaching strategies to improve students’ ability to integrate form and context to construct an appropriate theme.

In response to research question 2, “What are the characteristics and differences of social knowledge construction in the CSCL environment discussion activities of the control group and experimental group?”, we found that the main characteristics of the online discussions in the two groups was knowledge sharing. The sharing and comparison of these opinions may inspire students to further explore knowledge (Hou et al., 2008). Previous studies in similar contexts have also found similar results (Hou et al., 2015). However, the students in the experimental group were more intent on asking and answering questions to clarify disagreement about questions (KC2) and to negotiate the meaning or co-construct knowledge (KC3) than were the control group students. Moreover, students in the experimental group with the FTC model guided scaffolding had more discussion behavior codes than students in the control group without the scaffolding. In other words, the FTC model, as a guiding mechanism for the creation of artificial art, implies a process of knowledge construction. As Rojprasert et al. (2020) indicated, the construction of artefacts “promote[s] the internal activity of constructing knowledge through the external activity of constructing a representation or manipulation of that knowledge” (Clinton & Rieber, 2010, p. 764). Additionally, the higher level of knowledge construction (i.e., KC4, KC5) was still relatively limited in the experimental group. This may be due to the fact that the discussion period for this study was limited to 2 weeks, and students may have taken a less cognitively loaded approach to the discussion. Previous research has shown that providing sufficient time for online discussions helps to promote higher level thinking, as students may need more time for reflection (Hou et al., 2015; Scherling, 2011). Therefore, this situation might lead to a lack of higher-level knowledge construction in the discussion. These results may provide teachers with recommendations to improve the design of teaching experiments in the future.

In response to research question 3, “What are the differences in the sequential patterns of social knowledge construction in the CSCL environment discussion activities of the control group and the experimental group?”, we found that the behavioral sequences KC1-F→KC1-F and KC1-T→KC1-C reached statistical significance in the online discussions of the two groups of students. This means that the two groups found it easy to reach agreement as a result of sharing knowledge and ideas (Zhang et al., 2022). However, this study also revealed that the experimental group showed more advanced phases of discussion behaviors (i.e., KC3-F→KC2-C, KC3-F→KC3-T, KC3-T→KC3-C, KC3-C→KC3-F, KC4-F→KC2-F, KC4-C→KC1-C). Our findings are similar to those of previous researchers who noted that integrating effective learning strategies into the flipped classroom has the potential to promote students’ higher-order thinking (Chiang, 2018; Hwang & Chen, 2019). Additionally, it is interesting that more exchange of information occurred in the experimental group, such as KC2-F→KC3-F, KC3-F→KC2-C, KC1-C→KC4-C, and KC4-C→KC1-C, indicating that they engaged in more interaction and focused on co-constructing new knowledge during the activity. As Hou et al. (2008) suggested, during in-depth discussion, new questions might be created at the KC2, KC3, and KC4 stages to form a more in-depth dynamic discussion model. As a result, the FTC model guidance scaffolding is one of the key elements to help learners conduct reflection and knowledge construction.

In summary, the study provided a better overall process of discussion activities using the FTC model guidance scaffolding including the differences between the control group and the experimental group. Therefore, in the practice of photography education, the FTC model guidance scaffolding offers instructors a new discussion strategy to enhance learners’ ability of knowledge construction when analyzing the meaning of photographic works.

6. Conclusions and suggestions

In this research, we proposed a pedagogical design of FTC model guidance scaffolding to help students learn conceptual knowledge in a photographic course. Although Sandell (2006) proposed the FTC model to help learners create and identify layers of meaning in artworks, there seems to have been no investigation into the impact of the FTC model on learners identifying the level of meaning of visual artworks and behavior patterns of knowledge construction. Therefore, the main implication of this study is the introduction of the FTC model guidance scaffolding to support online asynchronous discussions on the multi-level meanings of visual imagery, and further comparison of differences in knowledge construction and behavioral patterns between the experimental group (i.e., using the FTC model guidance scaffolding) and the control group (without the FTC model guidance scaffolding). This study also shows that students who use the FTC model guidance scaffolding to support their online discussion activities can improve their performance. Therefore, this study can be used as a pedagogical reference for teachers of visual literacy and photography education to enhance students' ability to construct knowledge about the multi-layered meanings of visual images.

Through sequential analysis and the quantitative content analysis of knowledge construction, this study found that more discussions took place in the experimental group, especially "exploring opinions and concepts or the meaning of communicating." In a further analysis of online discussion behavior, this study revealed the behavior sequence of the experimental group, realizing more discussion behaviors and a diverse social knowledge construction process. However, the interaction at the level of knowledge construction in KC5 was not present in either of these two groups. Although the FTC model to some extent facilitated students' interactive behaviors and knowledge construction, their higher level of knowledge construction still had room for improvement. Moreover, the small sample size and exploratory nature of this study may limit the generalizability of the findings. Therefore, some suggestions are provided as follows.

First, Line was used as the online discussion platform for this study. By using Line, students can easily interact and share information (e.g., pictures, videos, texts, etc.) via different digital devices (e.g., smartphones) without the constraints of time and space (Chen & Li, 2010; Marek & Wu, 2012; Wu et al., 2017). However, with the development of new technological tools and the popularization of information networks, many new tools have been provided for online collaborative learning, such as online discussion forums and mobile instant-messaging apps. Studies have shown that these tools show different results in terms of knowledge construction and affective aspects when promoting collaborative learning; for example, the use of the Knowledge Forum can promote more knowledge-building communication than mobile instant messaging applications, but mobile instant messaging applications support more affective interaction (Sun et al., 2018). It is therefore suggested that future research could investigate whether the FTC model combined with other discussion platforms (e.g., Knowledge Forum) with some specific functions and applications could enhance the construction of higher levels of knowledge.

Secondly, future research will increase the analysis of the content of off-topic discussions. Social interaction includes conversations that are or are not related to the topic of learning. However, off-topic discussion provides an activator for creating the team atmosphere and cohesion. Several studies have shown that off-topic social interactions are not only related to interpersonal relationships but also to cognitive level and social knowledge construction (Lin et al., 2016; Hou & Wu, 2011; Kreijns et al., 2007). Therefore, it is necessary to further analyze the non-thematic types of social interactions; future research can be carried out on the qualitative analysis of off-topic content and the impact of topic deviations on collaborative online learning.

Finally, this study did not explore the reasonable effects of individual differences such as age and gender; therefore, future studies are encouraged to consider various individual characteristics as the control variables setting in the designed model.

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Fostering academic citizenship through ubiquitous technologies in an online academic conference: A framework and its implications

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ABSTRACT: Based on the concept of Communities of Practice (CoPs), this study describes the design and implementation of an online academic conference, Pedagogy and Practice in Technology Enhanced Language Learning (PPTELL) 2021, as a backdrop for exploring how to effectively promote the development of academic citizenship within the PPTELL CoP. To address this, we propose a framework focusing on four interrelated and interdependent dimensions: ubiquitous technologies, social practice, knowledge building, and academic citizenship. The conference utilized Zoom, Second Life, Slido, and several social media apps for various sessions and activities. A triangulation design was employed to analyze data from a post-conference online survey and observation notes. Our findings highlighted the effectiveness of the design in fostering academic citizenship, supported by multiuser virtual worlds like Second Life that enabled social engagement and knowledge building. We also discuss potential solutions to the challenges encountered, taking into account the nature of academic and higher education environments today.

Keywords: Communities of Practice, Academic citizenship, Technology enhanced language learning, Virtual technologies, Peripherality

1. Introduction

Since Lave and Wenger (1991) first introduced the concept of communities of practice (CoPs), it has been widely used to explain the collective learning process of people in shared fields (e.g., Cruess et al., 2018). A CoP is composed of three elements: the domain, the community, and the practice. People are connected through a network because of shared interests. To pursue their shared interests, they are committed to get together and participate in activities to share, discuss, collaborate, and support each other. This process enables them to form a community and establish reciprocal relationships. They act as practitioners in the community of practice as they also share practical experience. For example, as part of their role as academic citizens (Macfarlane, 2006), educators establish a community of practice with the aim to improve their knowledge and skills in the field of education through expertise exchange, experience sharing, and professional dialogue, thus creating a professional learning community (Tam, 2015).

Academic associations, such as the Taiwan Association of Pedagogy and Practice in Technology Enhanced Language Learning (PPTELL), serve as one type of CoP. PPTELL, as an emerging CoP, has attracted a group of TELL researchers at all career stages to regularly share ideas and experiences and learn from each other. This sharing often occurs via forums such as international conferences. According to Lan et al. (2021), international conferences generally aim to facilitate experience sharing, professional development, community building, and interpersonal connection. The achievement of these goals also contributes to academic citizenship, which Macfarlane (2006) defines as the critical role academics play in sustaining academic communities and their interaction/engagement with the wider community through making practical impacts. In fact, an international conference can be considered a CoP if these goals are realized.

When an international conference is hosted physically and attendees meet in person, the goals of interpersonal interaction, expertise exchange, and experience sharing are relatively easy to accomplish (Raby & Madden, 2021). However, it becomes more challenging when an international conference is hosted fully online (Hoffman et al., 2021). In the aftermath of the COVID-19 pandemic, many international conferences, including PPTELL, moved online (Lan et al., 2021), which posed challenges in establishing and maintaining a sense of community (e.g., Hoffman et al., 2021). Technically speaking, promoting social interaction between oral presentation

sessions and during poster sessions can be particularly challenging in online environments (e.g., Achakulvisut et al., 2021).

The Fourth PPTCELL Conference (PPTCELL 2021 hereafter) faced similar challenges to many other fully online conferences. Following the online PPTCELL 2020, the PPTCELL 2021 once again was shifted online. Taking into account lessons learned from the PPTCELL 2020 conference (Lan et al., 2021), new strategies were necessary to accommodate the needs of interpersonal interaction, social engagement, and knowledge exchange. The strategies adopted included real-time online poster sessions and social interaction among conference participants during the three-day event, facilitated using a 3D multiuser virtual platform.

Building upon suggestions and feedback gathered from participants in the PPTCELL 2020 conference (Lan et al., 2021), the planning and execution of the PPTCELL 2021 conference concentrated on two key aspects: (1) fully capitalizing on the capabilities of ubiquitous technologies to provide an immersive and engaging online conferencing experience, and (2) employing academic citizenship to fortify the social practice of the PPTCELL CoP. Academic citizenship, as defined by Macfarlane (2006), refers to the vital role that academics fulfil in supporting academic communities and fostering interaction and engagement with the broader community by making practical impacts. In the context of PPTCELL 2021, the conference aimed to cultivate academic citizenship by encouraging collaboration, knowledge sharing, and social interaction among its participants.

Underscoring the aims of the study, these two areas led to the formulation of the following research questions:

- Which technological platforms and tools proved to be most effective in enhancing participant engagement during an online international academic conference?
- In which ways and to what degree did the platforms and tools promote interaction and engagement among members of the PPTCELL 2021 CoP?
- What implications does this innovative design hold for the theory and practice of CoPs concerning online academic events and beyond?

The subsequent sections elaborate on the theoretical foundation that underpins the CoP in this study. A framework is proposed to contextualize the design of the PPTCELL 2021 conference, which consists of four emerging dimensions that are interrelated and interdependent in alignment with the objectives of this study.

2. Literature review

2.1. Community of practice

Following Lave and Wenger (1991), the term community of practice (CoP) was defined by Eckert and McConnell-Ginet (1992) as:

An aggregate of people who come together around mutual engagement in an endeavour. Ways of doing things, ways of talking, beliefs, values, power relations – in short, practices – emerge during this mutual endeavour. As a social construct, a CoP is different from the traditional community, primarily because it is defined simultaneously by its membership and by the practice in what that membership engages (p. 464).

This definition emphasises the dynamism, richness and complexity of the concept of a CoP (Holmes & Meyerhoff, 1999) and the notion of practice in social settings. As later Wenger (1998) insists, learning is an inevitable aspect of life that is fundamentally a reflection of social processes. He examines how an individual becomes a member of a community – joining a new workplace, a group, or even a new family through marriage – all involves learning. To ensure individuals appropriately perform in this process of becoming a member of the community, peripherality is key as defined by Lave and Wenger (1991), which is a characteristic of ways of belonging in the social world. Individuals may choose to gradually move from a peripheral membership to take on a core membership, while some may prefer to remain on the periphery (Holmes & Meyerhoff, 1999). In order for new members to develop into experienced members and engage in more interactive activities, efforts should be invested to provide opportunities for “legitimate peripheral participation” (Lave & Wenger, 1991, p. 37). Initial participation often means engaging in simple and low-risk tasks through peripheral activities and becoming more familiar with tasks, speech and organising principles and other community members. Lave and Wenger (1991) elicit three levels of participation relative to the periphery. First, central participation, implying that there is a centre, politically, physically, or metaphorically to a community with respect to an individual’s status in it. Second, complete participation, which suggests a closed domain of knowledge or collective practice

that is measurable by newcomers or new members to the community. This means that individual participants can evaluate efforts invested in contributing to the community and that they can adjust participation accordingly. Full participation is then intended to focus on justice and diversity of relations involving different forms of community membership. This may involve partial participation (or not), where newcomers' participation should not be framed in a fixed way – that is peripherality, suggesting “an opening, a way of gaining access to sources for understanding through growing involvement” (Lave & Wenger, 1991, p. 37-38). Conferences provide one such opening.

2.2. Online community of practice

According to Wenger (1998), three dimensions of a CoP are crucial to understanding and implementing the concept in practice: (1) mutual engagement, (2) a joint negotiated enterprise, and (3) a shared repertoire of negotiable resources accumulated over time (p. 76). As Liu (2012) states, the online CoP focuses on a domain of interest involving a group of people who share and develop knowledge, beliefs, values, and experiences through regular social interactions facilitated by technologically mediated communications. However, it is essential to acknowledge that sustaining regular interactions in online conferences might be challenging, given the ad-hoc nature of such events (Pedaste & Kasemets, 2021). Indeed, online CoPs require more than just technological tools to maintain regular and meaningful interactions (Moreira et al., 2022; Wu & Yu, 2022).

Considering this nuanced understanding of online CoPs, further research is needed to explore how an online conference can adopt CoP as a conceptual anchor for its design while addressing the challenges of sustaining regular interactions and fostering knowledge development. Existing research has indicated that the online CoP has supported various aspects of professional learning and development, such as digital literacy (Bostancıoğlu, 2018), interculturality (Hajisoteriou et al., 2018), pedagogy (Wang & Lu, 2012), self-efficacy beliefs (Inel Ekici, 2018), and effective communication with peer teachers (Hou, 2015). Moreover, positive teacher CoP impacts on student learning outcomes have been demonstrated through blogging (Zandi et al., 2014). There has also been growing interest in exploring how social media platforms and embedded features and tools support educators' online CoP, with examples including WeChat (Xue et al., 2021; Qi & Wang, 2018), Facebook, and Twitter (Goodyear et al., 2014; Wesely, 2013; Wong et al., 2011). However, the gap in the literature regarding online CoP in the context of online conferences warrants further investigation.

2.3. The role of technology in developing academic citizenship through the community of practice

Macfarlane (2006) asserts that an essential part of academic citizenship is educators and practitioners actively engaging in CoPs. Often a CoP provides a location for participants to perform their role as academic citizens in a range of ways, including mutual knowledge building through the sharing of research and experience, providing social and professional support to each other, and creating opportunities for research and other forms of collaboration. McDonald and Star (2008) explore the concept of CoPs in academic communities through a case study in an Australian university. They reported that the emerging academic CoP provides a location for individual academics who are new to the institution to focus on learning and teaching against a background of existing tensions in the higher education environment – casualisation, the competitive nature of the environment, and a maxim of “publish or perish” (p. 235). They argue that the CoP is a safe arena for reflexive practice and collaborative efforts in overcoming the challenges of mass education, one example being the increasing diversity and complexity of student cohorts in higher education.

One space where academic CoPs often gather and interact is at academic conferences. As noted by Macfarlane (2006), conference attendance is an important opportunity for academics to fulfil their obligations as academic citizens to contribute to the (disciplinary or expertise) community. Digital technology has become increasingly ubiquitous in society over recent decades, penetrating all aspects of our lives. CoPs and academic conferences are no exception to the increasing presence of digital technology. For some time now, digital technology has been seen as a potential means of enhancing various aspects of academic conferences, such as social interaction and knowledge building. At the same time, questions about the effectiveness of digital technology to value-add to traditional approaches to running academic conferences have attracted academic attention. Jacobs and McFarlane (2005) state that little attention at that time had been paid to research conceptualising an understanding of knowledge building as a conference practice or to developing a means of assessing to what extent academic conferences are deemed successful in this regard. Moreover, the role of technology in enhancing this practice was ripe for further investigation. Their study of the introduction of a range of new communication technologies into a face-to-face academic conference revealed that while digital technologies have the potential to contribute

to the achievement of the goals of a CoP, new skills and practices are required by participants to facilitate the effective use of new technologies and support the knowledge building process important to academics attending conferences.

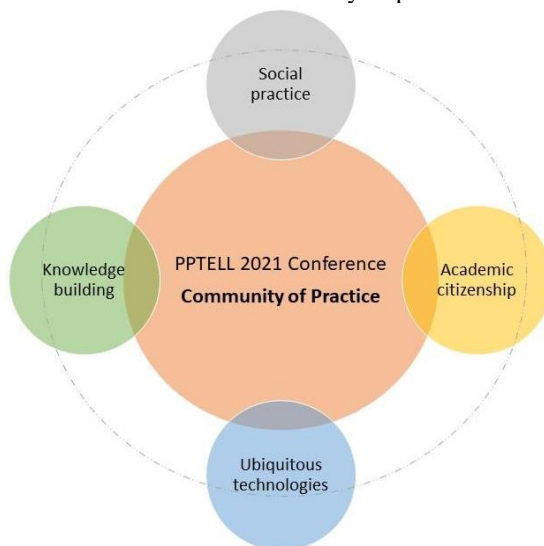
In addition to knowledge building, academic conferences also provide participants with important avenues for social interaction. During such interaction attendees can learn more about others and their work and can tell others about themselves and their own work. McCarthy et al. (2004) argue that traditionally, opportunities for such interaction are not evenly distributed due to factors such as one's status within the CoP, level of participation (e.g., new and peripheral, established and central, etc.), one's native language, and so on. To distribute opportunities more evenly to participants, they designed and put in place a suite of proactive display applications. This approach enabled attendees to easily reveal something about their background and interests, and thus potentially facilitate interaction. Analysis of the observation data and individual participant's responses to a survey revealed that while the design and implementation of the applications did create new opportunities for interaction, some attendees felt the displays were a distraction.

The concepts of CoP and academic citizenship and exploration of their practical application in varying forms and settings provide a useful prism through which to view the role and requirements of academic conferences in academic life. In organising the PPTELL 2021 conference, several emerging dimensions that had a significant impact on the construction of our community of practice were noticed. In response, a framework was proposed to address concerns and challenges of developing a sustainable PPTELL community of practice in the face of severe limitations imposed by the COVID-19 pandemic.

3. A proposed framework

Our work is situated and informed by Lave and Wenger's (1991) Communities of Practice placing the emphasis on learning as "an integral part of generative social practice in the lived-in world" (p. 35). We propose a framework to explain how our innovative strategies were designed to serve and contribute to the PPTELL conference and community and to fully utilise the affordances of ubiquitous technologies to engender an engaging online conferencing experience and strengthen the social engagement and practice of the PPTELL CoP. The framework outlines the ways each dimension interacts with the others to meet the specific goals of the 2021 conference and to address the pitfalls identified in the 2020 conference (Lan et al., 2021).

Figure 1. A proposed framework enables the community of practice through an innovative design



The interplay of language, technology, and learning is the foundation of the overall, amorphous PPTELL CoP. As Lave (2019) points out, within the larger, less structured community, participants can at times feel somewhat disempowered in terms of opportunities to move towards more intensive participation. Conferences, by bringing members of the community together regularly for set periods of time, can potentially be empowering by providing new opportunities for articulation between the more amorphous community that exists between conferences and the community created by and during conference participation and interaction. Conferences provide a focused location where each participant can connect to the practice of interest and other members of

the community in different and dynamic forms. However, the transition from physical to virtual conferences may lead to significant differences in the sense of “focused location” (Falk & Hagsten, 2021). In times of large-scale disruptions, such as the COVID pandemic, ubiquitous technologies, such as Second Life, Zoom, social media, and other online platforms, afford and enable ongoing legitimate peripheral participation (Lave & Wenger, 1991).

In the professional learning context of an academic conference, participants at any career stage can share and exchange knowledge with interest, passion, and commitment to create further impacts at the nexus of language, technology, and learning. “Being there” and “being together” (Lehman & Conceicao, 2010, p. 12) have been critical in the intentionality of different learning environments and developmental activities for individual participants. The informed use of digital technologies has brokered a sense of social presence and engagement. Differing from social presence in the Community of Inquiry framework that focuses on facilitating and supporting social, cognitive, and teaching presence in online education (Garrison et al., 2010), individual participants in the PPTELL community of practice and learning context are not linearly situated and are citizens in both the academic and the digital society at large. As part of their professional agency and attributes, each participant in the conference helps develop positive and reciprocal relationships that help them evolve as potential collaborators, work partners, and colleagues where distributed leadership (Spillane et al., 2001) is manifested with shared activities as leaders, providing opportunities for both leadership and followership in this community of practice (Lave, 2019). Embracing our complex and evolving professional identities as researchers, educators, practitioners, and academic citizens, the PPTELL conference is a location representing a situated community of practice that creates conditions for interaction with the four dimensions of our proposed framework to intensify and enhance academic intellectual, social, and affective engagement. Both formal and informal interaction is supported by the combination of several different virtually afforded multimodal resources in the online conference-based community of practice.

Considering the potential differences between physical and virtual conferences, we propose a revised framework that takes into account the unique challenges and opportunities presented by virtual conferences (Falk & Hagsten, 2021; Seidenberg et al., 2021; Wu & Yu, 2022). The four dimensions illustrated in Figure 1 interact with one another and highlight interdependence, emphasizing peripherality as a core value of the community of practice, which supports academic peers engaging in ongoing learning and development. Guided by this proposed framework, we unpack our approach to enhancing participation in the PPTELL 2021 conference through analyzing diverse ubiquitous technologies and exploring how they have contributed to the design and implementation of the conference in response to the needs of individual participants in the PPTELL community as well as among this contextualized, specifically online conference-based community of practice.

4. Our design

4.1. PPTELL

The Taiwan Pedagogy and Practice in Technology-Enhanced Language Learning Association (PPTELL Association) was established in July 2020 with a strong focus on promoting collaboration among researchers in the fields of Technology-Enhanced Language Learning (TELL) and Computer-Assisted Language Learning (CALL) to contribute to research on a global scale. The PPTELL Association originated from the Technology Enhanced Language Learning Special Interest Group (TELL SIG) under the Division of Information Education, Ministry of Science and Technology. TELL SIG has over 200 members based in Taiwan, Singapore, Hong Kong, Macau, New Zealand, and Australia. The PPTELL Association has organized three successful conferences that have connected researchers, educators, and practitioners to discuss the integration of language learning theories and advanced technologies for cultivating learners’ critical competencies. Each conference theme emphasizes the contemporary requirement of competency-oriented and contextualized language learning, with rich and diverse topics including smart learning environments, AI, robotic technology, augmented/virtual reality, big data, mobile computing, and educational games. PPTELL’s work in the TELL field is essential to the advancement of language learning technologies and their impact on education.

The 4th Pedagogy and Practice in Technology Enhanced Language Learning (PPTELL 2021) conference, which drew approximately 100 participants from various countries, was a hybrid online event held from June 28-30, 2021. The conference revolved around the theme of contextualized multimodal language learning (CMLL), with the primary objective of exploring the potential of technology to enhance language learning effectiveness across diverse contexts. The conference centered on examining the impacts of multimodality in language learning, including how technology, learning environments, and pedagogical approaches have influenced learners and instructors in contemporary classroom settings.

4.2. Choosing platforms

Regarding the choice of an online conference platform, ease of use and technical support are seen as critical because some participants and speakers are unfamiliar with operating complex conferencing software. Zoom, Google Meet, Microsoft Teams, and Cisco Webex are the most popular and commonly used videoconferencing apps in recent years. Each provides the functionality needed for videoconferencing, including video, screen sharing, chat, recording, and more. These platforms were investigated for their suitability (see Table 1). Due to wide adoption amongst academic institutions around the world and ease of use, and to the fact that it had been previously used successfully (Lan et al., 2021), Zoom was chosen as the main online platform for the opening and closing ceremonies and the keynote and parallel sessions (see Table 2).

While Zoom is an excellent platform for more formal sessions, it has limited capacity to mediate spontaneous social interaction, or what has been called “collision conversations” (McKendrick, 2020), where colleagues run into each other randomly (or intentionally) and have spontaneous (or planned) conversations that can lead to new ideas and collaborations or even facilitate established collaborations (Irving et al., 2020). As a platform for researchers to showcase their work and engage in meaningful discussions with their peers, poster sessions play a critical role at academic conferences. At many academic conferences, poster sessions create serendipitous opportunities for attendees who share the same research interests to meet and network with each other at scheduled times or during break periods. Informal socializing and networking also often occur during these breaks, when attendees and presenters can relax and enjoy refreshments, as well as at other social events that take place during the conference, such as dinners and social evenings (McCarthy et al., 2004). These activities and interactions are key features of a community of practice. They distinguish it from more formally structured interactions, such as those that occur in committees and meetings (Nagy & Burch, 2009). Poster sessions not only facilitate the exchange of scientific information but also foster opportunities for future collaboration. However, there are several challenges to organizing poster sessions in an online conference setting. First, it is difficult to replicate the in-person exchanges that are typical of physical poster sessions in a virtual setting. These interpersonal dynamics are critical to fostering meaningful connections and conversations. Second, technical limitations can hinder the seamless display and navigation of digital posters, potentially compromising the overall experience for both presenters and attendees. Finally, maintaining the engagement of the audience during an online poster session can be challenging, as it requires additional effort to overcome the lack of physical presence and body language cues.

In light of this, the organizers conducted research on various complementary multiuser platforms that could facilitate both poster presentations and spontaneous social interaction and networking. Table 3 presents potential platforms that could meet the conference’s needs, most of which entail significant costs, limited interaction, limited customizability, and/or require powerful computers to run. Consequently, Zoom was selected for the opening and closing ceremonies and primary presentations, while Second Life was chosen as the social networking platform for constructing a virtual poster exhibition area, refreshments area, and disco area to promote greater levels of social interaction. The following section will focus on the development of Second Life and how it can be effectively designed to facilitate the formal and informal social interactions desired at the PPTTELL 2021 conference.

Table 1. Online conference platforms survey

Platform	Monthly cost (US\$)	Max. number of attendees	Meeting length	Screen sharing	Chat	Personal message	Waiting room	Share files	Recording	Cross-platform support
Zoom meetings	Free	100	40min	✓	✓	✓	✓	✓	No	Windows, Mac, Web, Android, iOS
	\$ 15	300	24h						Yes	
	\$ 20	500	24h						Yes	
Google Meet	Free	100	60min	✓	✓	X	X	X	No	Web, Android, iOS
	\$ 12	150	24h						Yes	
	\$ 18	500	24h						Yes	
Microsoft Teams	Free	100	60min	✓	✓	✓	✓	✓	No	Windows, Mac, Web, Android, iOS
	\$ 5	300	30h						Yes	
	\$ 12.5	300	30h						Yes	

Cisco	Free	100	50min	✓	✓	✓	✓	✓	No	Windows,
Webex	\$ 15	200	24h						Yes	Mac,
	\$ 25	200	24h						Yes	Web,
										Android,
										iOS

Table 2. Selected academic conferences heled in the key online platforms

Platform	Conference
Zoom meetings	AECT 2020, 2021 AERA 2020 PPTELL 2020, 2021 GCCCE 2021 ICALT 2020 (with Remo), 2021 ICCE 2020 (with Remo), 2021 (with Airmeet)
Google Meet	ICITL 2020, 2021
Microsoft Teams	X
Cisco Webex	X

Table 3. Virtual worlds/virtual interaction tools survey

Name	Purpose	Attendee capacity	Cost	OS	Pros/Cons
Second Life	Virtual Interaction Poster Presentations	Unlimited	Participants for free	Windows, Mac	3D Environments, More Interactive / Hard to build
OpenSimulator	Virtual Interaction Poster Presentations	Unlimited	Free	Windows, Mac	Open source, 3D Environments/Virtual regions hosted on a multitude of different grids so can be confusing for new users
Gather	Virtual Interaction Poster Presentations	25 500 500	Free \$ 3 Per day \$ 7 Monthly	Windows, Mac, Web	Video conference functions, Customized space for 2D environments/ Difficult to get started
Remo	Virtual Interaction Poster Presentations	100 200	\$ 270 \$ 680	Web	Interactive virtual event platform, Support 2D/3D custom floor plans
Mozilla Hubs	Virtual Interaction Poster Presentations	30	Free	Web	3D Environments, Multiple devices / High-end devices, Host on AWS
Slido	Poster Presentations	unlimited	Free \$ 8 \$ 25	Web	User-friendly, High integration/ Only text-based interaction

4.3. Choice of 3D MUVE platform on Second Life

Second Life is an open sandbox world that has no embedded gameplay and that owes its heritage to the text-based social virtual world of LambdaMOO of the early 1990s (Bartle, 2010). Established in 2003 by Linden Lab, large communities of educators (Stevens, 2021) formed very early on in Second Life's history. Second Life provides many of the elements important to both international conferences and the communities of practice they represent. Two key elements are co-presence and social interaction (Kohonen-Aho & Vatanen, 2020). These elements are facilitated using avatars to interact with the virtual environment and others through the technical affordances of the platform for verbal and non-verbal communication (e.g., voice, text, gesture, multimedia functionality). Moreover, users can work collaboratively in the 3D virtual environment to co-create new digital content (Gürsimsek, 2014). For PPTELL 2021, a virtual poster exhibition hall and socialising space were custom designed and built for the conference that included a reception area (Figure 2), several poster stands (Figure 3), a virtual refreshments area (Figure 4), and a virtual dance floor (Figure 5).

4.4. Design and implementation of the 3D MUVE environment

The poster exhibition hall had fully customised conference branding and was used both synchronously and asynchronously. Via their avatars, visitors could move freely about to look at the posters and interact with other visitors, staff, and presenters. Sign boards with clickable links for the main conference website were also set up in the reception area.

Conference poster presenters were present at their respective stands at set times to talk about their research and answer questions from visitors. Posters could also be viewed at other times when presenters were not present and pre-filmed presentations could be viewed on the virtual video screens on each stand. Questions to the respective presenters could also be posted via panels on each stand linked to Slido (<https://www.slido/>; also see Table 3). Visitors arriving in the reception area (see Figure 2) were greeted by live PPTELL conference staff in voice and/or text mode and assisted with obtaining a virtual lanyard. They were also assisted with learning how to use the Second Life interface and guided to the different areas of the exhibition hall. Having live staff available to interact with visitors was one key element in making the virtual experience accessible, productive, and enjoyable for visitors.

Each poster stand was set up so that when talking in voice only those within the marked boundaries of each stand could hear what others at the stand were saying. This prevented audio disruption from other attendees who were talking in other areas of the exhibition hall, such as the reception area (see Figure 2), the refreshments area (see Figure 4) and the dance floor (see Figure 5). The virtual refreshments area was set up with virtual facilities such as chairs and tables and virtual food and beverages. This was aimed at making attendees feel more at home, and to create an environment that enabled relaxed communication (Cruz et al., 2014). Networking and social interaction was also facilitated by a dance party on the virtual dance floor at the end of the first day of the conference (see Figure 5). Cruz et al. (2014) argue that the use of avatars is important to the sense of presence that users can experience in virtual worlds like Second Life. They further argue that presence has an influence on collaboration because it helps users to better understand multiuser virtual environments and use them more intuitively.

Figure 2. Reception area



Figure 3. Poster exhibition stands



Figure 4. Refreshments area



Figure 5. Refreshments area



5. Methods

This study utilized a triangulation design for mixed methods research, drawing on post-conference online surveys and organizers' observation notes. The triangulation design is a research approach that uses multiple data sources or methods to increase the validity and reliability of research findings (e.g., Hawkey, 2006; López & Tashakkori, 2006). By employing multiple data sources, the study aimed to answer the first two research questions and enhance the validity of the research. Combining both methods provided a more comprehensive and accurate understanding of the research questions, thereby improving the overall quality of the study. The selection of each instrument was based on the study's aims, ethical considerations, and data collection and analysis procedures, which are explained in detail as follows.

5.1. The post-conference online survey

As soon as obtaining the human ethics approval by Researcher B's institution, and the conclusion of the PPTeLL 2021 conference, an online survey using Google Forms was distributed to all participants ($n = 100$), from which 25 valid responses were collected for analysis. The survey was voluntary, and respondents remained anonymous throughout. Its objective was to gain insight into the participants' experience of a fully online academic conference, their perceptions of technological tools and platforms used for knowledge building and social practice, and their individual development of academic citizenship through interactions with the global PPTeLL community.

The conference organizers designed a total of 34 survey questions, consisting of both closed- and open-ended questions. Firstly, the survey inquired about the preparation work prior to the conference, including the choice of communication software, information dissemination, and provision of tutorials. Secondly, it addressed the user experience of the conference platform, encompassing the use of Zoom and Second Life platforms, security issues, scheduling, discussion and interaction, and video sharing, among other factors. Thirdly, the survey explored the quality and satisfaction of conference activities, including paper presentations, social networks, poster exhibitions, Slido application, break time, opening and closing ceremonies, keynote speeches, and panel discussions, among others. Finally, the survey asked about personal experiences and feelings, such as preparation work, the most challenging aspects, favorite experiences, meeting expectations, potential areas for improvement,

recommendations for other scholars, and plans for future participation. These questions provided valuable insights into attendees' evaluations and feedback on the conference, enabling organizers to extract meaningful information to further enhance future conference planning.

Descriptive data analysis was employed to report on general trends found in selected closed-ended questions, while thematic analysis was used to analyze the open comments. To ensure the reliability and validity of the analytical process, two researchers were involved in the thematic analysis, following the procedures outlined by Braun and Clarke (2006). Researcher A retrieved the open-ended responses and reviewed them, highlighting important quotes in an online Excel worksheet, while Researcher B coded and identified the emerging themes, along with the useful quotes that were reviewed and agreed upon by Researcher A.

5.2. Observation notes

The authors of this study were key members of the PPTELL 2021 conference organizing committee, whose observation notes were collected after the conference as delayed reflective accounts on what they experienced and observed when acting in multiple roles in different sessions (Baker, 2006). An observation table (see Appendix A), based on the preliminary analysis of the survey responses focused on four key themes, comprising interaction, communication, challenges, and suggestions. Thematic analysis (Braun & Clarke, 2006) was employed by Researcher B and the emerging themes were reviewed by the other three researchers.

6. Results

6.1. Ubiquitous tech supports knowledge building & academic citizenship

As shown in Table 4, most of the respondents were based in the Asia-Pacific region. Among these 25 survey respondents, two main areas of research interest were reported: TELL (n=23) and Linguistics (n=2). 14 respondents had experience of an online academic conference before PPTELL 2021 while 11 had not. This finding correlates with Table 5, where the respondents with experience of using Zoom in their academic role mainly used it for teaching activities and scheduled meetings. Only five responses specified that Zoom was adopted for online conferencing and workshops in their academic settings. The 11 respondents who had never attended a fully online conference other than PPTELL 2021 reported not having any Zoom related activities in their academic role. Given Zoom was the main platform used for PPTELL 2021 for main sessions, pre-conference tutorials were conducted to prepare participants for attending these sessions. As indicated in the responses, at least these 25 respondents considered these tutorial sessions necessary and helpful, with some noting that “the information provided appeared to be sufficient” and “very helpful and unique in the international conference.”

Table 4. Survey respondents located during the PPTELL conference period in 2021

Respondent location during the PPTELL conference days	<i>N</i>
Australia	2
Canada	1
Hong Kong	3
Home	2
Peru	1
Taiwan	15
N/A	1
Total	25

Table 5. Frequency of mentions indicates multi-purposes of Zoom for academic work

Purpose of using Zoom in respondent academic activities	Frequency of mentions
(Language) Teaching	10
Conference and workshops (incl. PPTELL 2020)	5
(Regular) Meeting (incl. faculty meeting)	8
N/A	11

A question regarding satisfaction with the discussion and interaction on Zoom received a very positive response – all 25 respondents reported on their “really enjoyable” experience of using Zoom for knowledge building

through intellectual and insightful discussions before, during, and after keynote and oral presentations at the conference.

Two instant messaging group chats on Line and WeChat were also set up for any urgent communication before and during the conference. All 25 survey respondents confirmed their familiarity with the apps and used either or both during the conference. There was a high level of satisfaction due to timely updates, including reporting and sorting out technical issues and timing announcements about parallel oral presentation sessions conducted in different Zoom meeting rooms. Table 6 demonstrates the survey respondents' preferences over the two apps.

Table 6. Respondents preferred social media apps for keeping in touch on PPTELL 2021

Preferred social media apps for keeping in touch	<i>N</i>
Both Line and WeChat	2
Line	18
WeChat	3
Other	2
Total	25

Although respondents were satisfied with Zoom's functionality and stability, one mentioned Google Meet as an acceptable alternative platform, while another suggested, "Zoom is fine as we don't have any better options in the market!"

In response to the identified issues arising from the emergency shift of the conference online (Lan et al., 2021), Second Life was introduced as the platform for the poster presentations and social networking. Academics in higher education generally value conferences highly for developing academic citizenship. The survey respondents reported a positive attitude to having a tour in Second Life during the pre-conference tutorial, and 23 selected "yes" to indicate the appropriateness of adopting Second Life for this type of presentation and social practices. They used keywords such as "good for networking," "very innovative and interesting," "fun," "impressive," "quite special," "intriguing to present the posters via Second Life," and "really good and new experience." These keywords reflect the excitement of these respondents as participants.

During poster presentation sessions, some respondents indicated that they withheld questions with the expectation of interacting with poster presenters/authors on Slido, embedded in Second Life to support asynchronous Q and A. Two of them mentioned,

...it's real-time and user-friendly. But it would be better if it would send a notification to me whenever people drop questions.

I didn't receive any answers by the end of the conference.

Survey results show Slido was not used by most participants. A few respondents said this was because they did not see many interactions on Slido, although two comments highly recommended Slido for asynchronous Q and A as "it was real-time and user-friendly."

The following comments articulated and highlighted the aspects of social practices that Second Life afforded, even enhancing the experience in ways that real-life conferences may not be able to contest.

Second life indeed made the poster exhibition more interactive. Guests could share their questions or thoughts through vocal calls or simply through sending messages with each other. There was even a bar for guests to dance and chat! I was also surprised by the zoom-in function of Second Life, in which we can clearly see the information on the poster.

... without a doubt, Second Life gave us a cool experience of interacting with other attendees and took part in the exhibition in a virtual way.

I met one of the US professors and had quite a long chat with him. I also had a long chat with a New Zealand colleague as well.

One respondent also appreciated the use of Second Life to help fill the breaks during the conference. In response to the question "Were you bored while waiting for the next session" they responded, "not at all. Second life is great! The music played during the break was also nice. Feel relaxed."

A few respondents reported that they had a problem accessing Second Life. As one respondent specified, “it was a bit time-consuming to install the application and create an account.” At the same time, another respondent did not think that this platform supported the poster presentation sessions well as shown in the comment below:
No, I don’t think so. In fact, the words are too small to read through on SL. Besides, it’s not too easy to move or scroll down the poster.

6.2. Overall satisfaction and appreciation of the online conference organisation

Equipped with ubiquitous technologies, the PPTTELL 2021 conference was perceived as a mostly “100%,” “excellent,” and “strongly recommended” TELL conference by all 25 survey respondents. They also believed that an online conference like this was “innovative,” with one respondent commenting, “it opens my vision regarding how to organise the conference, and I’m exposed to a lot of interesting and creative research projects.” Similar comments focused on the nature of the academic conference, which was for building knowledge as it “covered a lot of research ground that is of interest,” “provides great opportunity to keep learning about the latest trends in TELL” and so on.

Most respondents also shared their perceived highlights of the conference. These mainly related to the social networking activities on Second Life and to gaining insights from interacting with keynote sessions and presentations for knowledge building and development. Some examples are:

The dancing and socialising at the end of day 1.

The [dance] ball and drinking bar are just perfect and creative!

The scenes in the Second Life. It’s authentic, and I feel so real when people are asking questions about my poster.

Dance in second life.

Relating to CoP, the survey respondents considered PPTTELL annual conferences as a community that provided “the chance to get together” and “the opportunity to catch up with colleagues from around the world & to hear about their research.” One of the comments elicited this participant’s appreciation, passion, and sense of belonging to the PPTTELL community:

I always like PPTTELL conferences. It’s warm and welcoming. You don’t feel isolated in this conference as everyone is very nice and friendly. You learn a lot from each presenter at this conference.

I have been given a chance to listen to great scholars sharing their insights and opinions on the use of technology in enhanced language learning.

Survey responses also acknowledged unavoidable pitfalls of attending an online conference from home, some of which are discussed below.

6.3. Key challenges experienced by the survey respondents during the conference

6.3.1. Time difference

The PPTTELL conference was originally targeted for Pan-Pacific regions and attracted a great majority of participants living within the region. The subsequent rescoping of the PPTTELL association resulted in broadening its market to a global context not limited to Asia-Pacific. As a result, there were several participants at the 2021 conference from North and South America who suffered significantly from time zone difference related issues. As two of them reported on the survey,

Unfortunately, the time difference between Taiwan and Quebec is 12 hours. So the conference started too late for me. There is nothing you can do to avoid this problem, though!

For me, being in Peru (-13hrs difference to Taipei) was great until early afternoon sessions (13:00 or 14:00 Taipei Time)

Even those in more friendly time zones still found it difficult to squeeze in time for appropriate breaks during those conferencing days.

The time arrangement was appropriate for attendees, but not that appropriate for some volunteers. Some volunteers had to be online during the noon break, maybe it would be better to adjust the afternoon's schedule.

There wasn't enough break time for lunch.

6.3.2. Human-to-human face-to-face interactions

The open-ended questions asked participants to illustrate the most challenging aspects of participating in the conference. As expected, many respondents expressed their willingness and desire to physically gather and interact with other colleagues at the real-life conference event.

6.3.3. Technical issues

Not all participants found time to join pre-conference tutorial sessions, therefore technical issues were still apparent for several participants. Some explained that they wished they had more time for practice using the tools and platforms. They appreciated the professionalism of the conference committee and were amazed by the mostly smooth, impressive planning and operation experienced during the conference. Technical concerns leaned more towards "using Second Life," reflected in comments like, "it takes some time for my laptop to run SL, and my character can't move smoothly from time to time."

6.4. Conference organisers' observation notes

All the observers confirmed that social media apps (e.g., Line and WeChat) supported the interactions between conference staff and between staff and conference attendees to foster collaborative work and effective problem solving. One particularly noted, social media "helps overcome communication problems that might have caused by issues with Second Life or Zoom. Attendees have a continuous stable means of keeping in communication with assistants as they work through any technical issues with Second Life or/and Zoom."

It was also observed that it was essential to have conference staff or volunteers in Second Life to meet, greet and assist visitors. As one noted, "I observed a number of visitors to the virtual poster hall being 'tutored' by Kelly and the other assistants. Having someone constantly [at] present at the virtual reception desk for when visitors arrived seemed to be very welcomed by the visitors..." The interaction carried out in voice mode was also noted as "easy" and "upbeat."

One organiser commented that during sessions she chaired on Zoom she reminded attendees to turn their cameras on during Q & A sessions to "offer the presenters a sense of belonging to this particular community." The sense of belonging was also observed in the Second Life virtual poster and networking venue which afforded an "immersive" and "live" experience of the poster sessions that was absent from the previous fully online PPTeLL conference in 2020 held fully on Zoom. The same organiser recalled seeing each poster stand being "crowded with attendees" during live sessions, and that "some very valuable intellectual conversations" were happening. This addition of the 3D virtual venue illustrates the potentiality of multiuser 3D virtual environments to further satisfy CoP needs (formal and informal networking) for attendees participating in academic conferences online.

Organisers also acknowledged a challenge for any event held on VR world platforms like Second Life. As indicated in the survey, PPTeLL attendees experienced a range of technical issues when exploring Second Life. These issues, including "internet connectivity" and "bandwidth," were regarded as "problems hard to anticipate or resolve as they can vary quite widely from attendee to attendee." In response, another observer suggested considering the adoption of other tools, such as "Discord," for future online conferences. He explained that "Discord" can "...transmit conference information and event reminders through bots and can be used for voice communication to assist participants in solving problems." Another suggestion reported in the observation notes was to add more training or practice time with assistants to support attendees.

In the next section, discussions around the results that underpin the four dimensions in the proposed framework are presented. Centring academic citizenship, the PPTeLL 2021 conference as a CoP evidently provided

peripherality for the conference attendees to experience knowledge building and social practice with the support of appropriate technologies.

7. Discussion

Our findings suggest that the PPTELL 2021 online conference garnered positive feedback from attendees, primarily owing to the inventive design enabled by Second Life for poster sessions and social activities. This observation was substantiated by the conference organizers, who were instrumental in both the design and execution stages. Despite facing minor technical challenges, primarily resulting from device constraints, internet connectivity, and bandwidth, most participants indicated that the conference successfully facilitated their immersion into their preferred virtual Communities of Practice (CoP) within the virtual environment. This engagement allowed attendees to interact with fellow academics and potential collaborators for knowledge building, experience sharing, and socializing while navigating virtual environments accessible through various digital platforms, such as Zoom, Second Life, Slido, Line, and WeChat. By fostering a virtual CoP, the PPTELL 2021 conference enabled the actualization of peripherality (Lave, 2019), empowering members at different career stages to partake in community events and social practices without concern for hierarchical structures or power dynamics. This approach highlighted the importance of reciprocity - learning from one another, sharing and exchanging knowledge and experiences, and offering formal and informal support - as the crux of academic citizenship, even when represented by avatars (Cruz et al., 2014). As a result, PPTELL 2021 was regarded as a “friendly” and “welcoming” academic conference, leaving an enduring impact on attendees from diverse backgrounds within the TELL community and beyond.

Although Slido was integrated into the Second Life poster stands to enable smooth, real-time communication between attendees and poster presenters/authors during and after live sessions, it was noted that conference participants were generally unaware of this functionality. Among those familiar with Slido, some expressed a preference for “notifications” to inform them of new questions and answers being posted to enhance their involvement in the Q&A sessions. With an ample number of standby assistants in the virtual world, this concern was considered relatively minor and could be readily addressed by providing additional training and practice sessions prior to the conference and increasing live assistant presence during the event. In contrast to the continuous participation enabled by in-person attendance at physical conferences, virtual academic attendees may need to manage multiple tasks, commitments, and substantial workloads and pressures before and during the conference (McDonald & Star, 2008), a factor warranting attention in future events.

Academic conferences are of significant value to most academics, who perceive them as a means of fostering their academic citizenship (Macfarlane, 2006). This viewpoint was supported by PPTELL 2021 survey respondents. Consequently, it is crucial to establish opportunities for social engagement and interaction within CoPs, such as virtual refreshment areas and dance floors (Figures 4 and 5), allowing attendees to enjoy “fun” and “relaxed” moments (Cruz et al., 2014) between formal scheduled sessions. At the PPTELL conference, attendees could converse with other participants in voice or text while partaking in virtual beverages or coffee. Regardless of their real-life dancing skills, Second Life provided a judgment-free environment for attendees to dance while “being there and being together” (Lehman & Conceicao, 2010). As the PPTELL conference attendees emphasized, these appealing features augmented social practices that may surpass those offered by real-life conferences. In conclusion, this study contributes to the innovative design of virtual Communities of Practice (CoPs) in online academic events in several ways. By effectively integrating Second Life, the study demonstrates how engagement and immersion can be facilitated, allowing participants to forge relationships and share knowledge beyond the constraints of traditional conferences. To optimize engagement, the study underscores the importance of addressing technical issues, providing support, and considering the various commitments of participants. Furthermore, our research illuminates potential advancements in the theory and practice of CoPs in the context of online academic events and beyond by incorporating opportunities for social engagement and promoting academic citizenship.

8. Conclusion

Drawing upon our proposed framework for devising online academic conferences, this study reinterprets peripherality within virtual Communities of Practice (CoP) to augment academic citizenship in conjunction with, and interrelated to, two other dimensions: social practice and knowledge building. This is achieved through the utilization of multiuser 3D virtual worlds (e.g., Second Life) and an array of technological tools and platforms. As a central feature of CoP (Lave and Wenger, 1991), peripherality is rooted in social contexts. During the

PPTeLL 2021 conference, a virtual CoP was established to immerse participants within multiuser virtual environments, enabling them to navigate among various platforms and tools while engaging in synchronous and asynchronous interactions with other attendees. Although our research offers meaningful insights, we recognize its limitations concerning the response rate. A mere 25 participants provided comprehensive responses, which may not be adequate for drawing reliable conclusions. This constraint was primarily due to the 34-question survey and the limited number of respondents willing to complete it in its entirety. Nevertheless, our research presents valuable perspectives on the challenges and opportunities presented by online communities of practice.

Furthermore, we acknowledge the intricacies of ubiquitous technologies and the potential for technical concerns to overwhelm online conference organizers. In the digital era and the rise of metaverses, we assert that this study illuminates the significance of recognizing and optimizing the potential of virtual worlds and other technologies and their integration into professional contexts, such as academic conferences, to enhance social practice and knowledge building experiences. Gourlay (2022) contends that interactions via video platforms like Zoom are “just not the same” as face-to-face encounters (p. 67-68), lacking many of the subtle communicative aspects inherent in physical interactions essential for human communication. Attempting to replicate real-world interactions on these platforms is deemed “futile” and “doomed to failure.” However, this conclusion “emphasizes the necessity of enhancing participants’ sense of relationality, connectedness, and inclusion in alternative ways and forums” (Gourlay, 2022, p. 67), which we argue this research demonstrates was accomplished to a certain extent through the incorporation of the virtual venue in Second Life.

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Students' interaction, satisfaction and cognitive presence in online discussions: Comparing novice and experienced instructors with distinguished interaction patterns

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ABSTRACT: This study compares the interaction patterns of a novice and an experienced instructor using Social Network Analysis (SNA) and content analysis and explores how students' interactions, degrees of satisfaction, and cognitive presence differ according to the different interaction patterns of the two instructors. Results showed some differences in the interaction characteristics between the sections. First, the experienced instructor was the most powerful actor in the course, while some students in the novice instructor's section showed higher outdegree centrality than the instructor. In addition, the novice instructor's section was a more active network than the experienced instructor's section in which the instructor showed the highest outdegree and indegree and also seemed to have more reciprocal relations. In terms of satisfaction and cognitive presence levels, the students in the experienced instructor's section in which the instructor focused more on triggering events or exploration activities, reported higher satisfaction than the students in the novice instructor's section. However, there was no significant difference in students' cognitive presence levels. A key finding of research suggests that instructors need to balance their participation, stimulate students' curiosity, and encourage brainstorming—rather than directly offering solutions—to improve students' satisfaction in asynchronous discussion-based online learning. This research also indicates that well-designed discussion topics may contribute more to developing students' cognitive presence than the instructor's interaction patterns. Finally, this research highlights the effectiveness of SNA and content analysis to explore instructors' and students' interactions on discussion boards.

Keywords: Online discussion, Interaction, Online instructor, Cognitive Presence, Social Network Analysis (SNA)

1. Introduction

Interaction is considered to be one of the most essential elements in educational environments. Merriam-Webster Dictionary (2023) defines interaction as “mutual or reciprocal action or influence.” It differs from communication, which refers to the exchange or transmission of information by verbal or nonverbal methods, in that communication can be one-way as well as reciprocal. Also, interaction can occur through communication, whereas there are instances where communication can occur without requiring any interaction. In online environment, three different types of interaction—learner-instructor, learner-learner, and learner-content interaction—have been especially emphasized for its potential to overcome the limitations of physical distance (Moore & Kearsley, 2011). Moore and Kearsley (2011) said, “Effective teaching at a distance depends on a deep understanding of the nature of interaction and how to facilitate interaction through technological transmitted communications” (p. 132). Other researchers have also suggested that interaction plays a critical role in the success of online learning (Alqurashi, 2019; Baber, 2020; Yousaf et al., 2022; Zhang & Lin, 2020). In particular, instructor interaction and facilitation have been known as an essential factor influencing students' learning participation, achievement, and satisfaction in online courses (Alqurashi, 2019; Du et al., 2022; Kuo et al., 2014). With the perceived importance of instructor interaction and facilitation for students' learning experiences and outcomes, researchers have explored instructor-student interaction in online courses with various methods. Specifically, previous researchers have analyzed the level of interaction and facilitation with surveys (Lei & Lin, 2022; Wang et al., 2022), frequency of instructor postings (Parks-Stamm et al., 2017), and through content analysis (Koch, 2021; Kwon et al., 2019). However, exploring interaction and facilitation patterns is very complex and challenging and thus various approaches are required to analyze them (Long & Koehler, 2021).

More recently, researchers have started to apply social network analysis (SNA), a method which focuses on relations and connections among social entities and the patterns and effects of these relations (Wasserman & Faust, 1994, p. 3), in exploring the dynamic process and patterns of interactions on discussion boards (Liu et al., 2022; Ouyang & Chang, 2019). However, little research has explored instructor interaction and facilitation characteristics in asynchronous discussion with SNA approaches. Nor has there been much SNA research into the effects of different instructor interaction patterns on students' discussion network attributes, satisfaction, and

cognitive learning. To fill in the gap, this research aims to explore instructor interaction patterns in discussion boards using SNA and content analysis. I also compared students' discussion patterns and their satisfaction and cognitive thinking abilities according to instructor interaction patterns. In particular, this research targeted the interaction patterns of a novice instructor and an experienced instructor because previous online teaching experiences and expertise have been known as important factors influencing instructor interaction and facilitation behaviors (Fidalgo & Thormann, 2012; Gurley, 2018; Long & Koehler, 2021). Specifically, the research questions for this study are:

- RQ1. What were the patterns of a novice and an experienced instructor's interactions on the asynchronous discussion boards?
- RQ2. What were the students' interaction patterns of the online discussion network in the novice and experienced instructor's course sections?
- RQ3. How did cognitive presence level and satisfaction differ according to the interaction patterns of the novice and experienced online instructor?

2. Theoretical background

2.1. Cognitive presence and satisfaction as learning outcome variables

Cognitive presence and satisfaction have been widely adopted by researchers to measure students' learning experiences and outcomes in asynchronous discussion-based online courses. Cognitive presence is one of the elements of the Community of Inquiry (CoI) framework that guides meaningful and successful learning experiences in asynchronous online learning with a socio-constructivist view (Garrison et al., 2001). Cognitive presence describes the extent to which learners can construct knowledge through reflection and discourse in online discussions. Researchers have previously used cognitive presence to measure students' cognitive learning outcomes, particularly higher-order thinking abilities in asynchronous discussion-based online courses (Garrison et al., 2001). Cognitive presence involves four phases: the first phase is the triggering event, which is being aware of a problem through feeling a "state of dissonance" or "unease resulting from an experience" (Garrison et al., 1999, p. 98); the second phase of cognitive presence is exploration, which involves searching for new information, knowledge, and alternatives to address a problem; the third phase is integration, which involves synthesizing and combining information; and the last step is resolution, which emphasizes the application of an idea or hypothesis to a real situation (Garrison et al., 1999). Researchers have used two different methods to measure the degree of students' cognitive presence: (1) quantitative survey (Akcaoglu & Akcaoglu, 2022; Lim & Richardson, 2021) and (2) qualitative analysis of discussion postings addressing the four phases of cognitive presence (Lee et al., 2022; Sadaf & Olesova, 2017).

Satisfaction is another key variable that is commonly used to measure students' affective learning outcomes. Bolliger and Halupa (2012) stated that student satisfaction can be an important factor to evaluate course and program effectiveness. Baruth and Cohen (2023) similarly described student satisfaction as an important indicator in determining the success of online learning. Indeed, many scholars have focused on different aspects of student satisfaction, including students' satisfaction with instructors (Sahawneh & Benuto, 2018), learning from online discussions (Sadaf et al., 2021), and overall online learning experiences (Lim & Richardson, 2021), to evaluate online learning outcomes.

2.2. The importance of instructor-student interaction in discussion boards

Many researchers have reported that students' successful learning experiences and outcomes in online courses can be determined by instructors' interactions and facilitation in discussion boards (Alqurashi, 2019; Du et al., 2022; Kuo et al., 2014; Ladyshevsky, 2013). For instance, instructor facilitation allows students to keep on track and helps them to address some challenges or conflicts in the discussions (Hew, 2015). Furthermore, Ladyshevsky (2013) also pointed out that, although the course design in six different sections of a post graduate managerial leadership course was stable, student satisfaction varied across all different sections. According to the scholar, the variations could have been caused by online instructors' interactions and other behaviors of managing and facilitating the students. Indeed, Ladyshevsky (2013) found that increasing in instructor postings including more social and teaching presence factors has positive impact on students' satisfaction with instructors' feedback and teaching on discussion boards.

Eom and Ashill (2016) also reported that instructor-student dialogue has a positive relationship with students' satisfaction and learning outcomes. The researchers found that instructor-student dialogue showed higher

predictive effects on learning outcomes ($\beta = .24, t = 6.11$) than on satisfaction. ($\beta = .08, t = 2.13$). More recently, Alqurashi (2019) revealed that learner-instructor interaction was found to be a critical predictor of student satisfaction and perceived learning in online courses while learner-learner interaction did not show any predictive effect on both variables. In particular, considering that recently a fair number of instructors teach courses which have been designed by other faculty, instructor interaction and facilitation in the discussion boards would be more important for establishing instructor presences and characters, which are likely to influence students' satisfaction and learning outcomes.

2.3. Patterns of novice and experienced online instructor interaction on discussion boards

As I discussed in the above section, instructors play a critical role in providing meaningful learning experiences through social and intellectual interactions with students. With the importance of instructor interaction, many researchers have emphasized that instructors need to be effective facilitators or guides in online learning environments (Kwon et al., 2019; Long & Koehler, 2021; Martin et al., 2020). Then which characteristics of instructors impact their interaction and facilitation patterns in online discussion boards? One of the probable potential factors in an instructor's interaction would be their level of experience in teaching asynchronous online courses. Indeed, previous research has shown the possibility that the quantitative and qualitative attributes of interactions and facilitation may differ between experienced and novice instructors. First, Fidalgo and Thormann (2012) compared student and instructor interaction from courses taught by an experienced and a novice instructor using the SNA method. As the result, they found that both the experienced and novice instructor played a primary role in their discussion networks. However, the researchers found that the discussion network which was facilitated by an experienced instructor seemed more student-centered, while the network in the novice instructor's course showed an instructor-centered model. More recently, Long and Koehler (2021) compared an expert and a novice instructor facilitation in discussion boards with SNA and content analysis. According to the scholars, both instructors were active facilitators and used facilitation strategies including social congruence, cognitive congruence, and content expertise frequently. However, they found that the expert instructor has the skills to adjust their facilitation strategies based on students' needs while the novice instructor tended to maintain the same strategies. Watson et al. (2018) also found that the instructor with expertise showed the flexibility by using different facilitation strategies on discussion boards based on course goals and learner needs. This research revealed that the experienced instructor tried to find a balance between using questions and giving helps or answers to students. Finally, Martin et al. (2019) suggested that instructors' years of online teaching experience has significant impact on their course design and facilitation.

The results of previous research imply that there may be some differences between novice and experienced instructors' interactions or behaviors in online discussion boards. However, despite the importance of instructor interaction, there have been only a few studies exploring the characteristics of novice and experienced online instructor interaction or facilitation using both SNA and content analysis.

2.4. Social network analysis research on student and instructor interaction

SNA refers to the method which is used to analyze relations between members in a network. Recently, educational researchers have started to take advantage of SNA to explore instructors' or students' interactions and relations in online discussion boards. Furthermore, they have studied the associations among students' interactions and relation patterns with learning outcome variables such as obtaining certificates (Joksimović et al., 2016), learning achievement (Lim, 2023; Saqr et al., 2022; Ye & Pennisi, 2022), problem-solving skills (Cheng et al., 2022), knowledge construction (Zhang et al., 2021; Zhao et al., 2016), and satisfaction with courses (Lim, 2023). For example, Lim (2023) found that students' outdegree and indegree centrality are not only interrelated but are also correlated with their perceived learning achievement and satisfaction with the course. Zhao et al. (2016) measured students' centrality and density in online discussion boards and compared knowledge construction levels between core and marginal students. In their research, they reported that most students remained at a lower level of knowledge construction, including sharing information and idea exploration rather than reaching higher knowledge construction levels, which involve negotiating, testing, and applying the constructed knowledge. Of course, in their research, there were some differences between core and marginal students. The number of postings from core participants was significantly higher than from the marginal group of students, and they showed more messages at higher levels of knowledge construction than the marginal participants, although most of the core students still stayed at lower levels of knowledge construction. More recently, Cheng et al. (2022) explored the relation between students' interaction patterns on asynchronous discussion boards and their problem-solving skills. They found that the density, outdegree and indegree centrality, and total number of individual connections in the discussion network were significantly related to

students' problem-solving performance. Taken together, the results of previous research show that SNA is an effective way to analyze instructor and student interactions and relationships. In addition, the research implies that learning satisfaction or achievement may be influenced according to interaction and participation degrees or patterns in the discussion network.

3. Methods

3.1. Context and participants

The data for this study were collected from two different sections of a fully online master's course in Learning Design and Technology (LDT) at a large Midwestern public university. The sections, which were offered over eight weeks via Blackboard, shared the same course design, content, and structure. The most significant difference between the two sections was the two instructors' experience in teaching asynchronous online courses. This study divided the two sections into novice and experienced instructors' sections based on previous research that defines novice instructors as those with less than three years of online teaching experience and veteran and experienced instructors as those with more than 15 years of service (Walsh et al., 2020). In this research, one section was taught by a novice instructor (less than 2 years' experience) and the other was taught by an experienced instructor (more than 20 years' experience). There were 15 students (5 male; 10 female) in the novice instructor section, while the experienced instructor's section had 17 students (1 male; 16 female). There was not a significant difference in the GPAs of the students in both sections before taking this course ($p > .05$).

In this course, all students were required to participate in discussion boards every week. Specifically, each student should have posted an initial response about a given discussion topic and then post 2-3 additional responses to move the group discussion forward. Students participated in the discussions in a variety of ways. For example, they could provide examples from their own experience, describe possible consequences, challenge other students' postings, pose a question, suggest a different perspective, or share related information from other sources. The discussion activity was graded according to the frequency and quality of postings. The discussions were worth 24% of the total score for the course.

3.2. Data collection and analysis

In this research, two different types of data sets were gathered. First, archived instructor and student discussion threads were extracted from week 1 to week 7 discussion forums, except for the week 4 discussion. The week 4 discussion board was not included because the instructors asked students to only upload individual postings without replying to other students' postings. The students' perceived satisfaction with their discussion experiences was assessed with a regular online course evaluation survey distributed by the university. The original survey consisted of 15 items evaluating students' satisfaction with their online course and instructor, but this study narrowed the focus to nine items specifically addressing students' satisfaction with discussion activities and instructors' interactions that may occur in discussion (e.g., "Class discussions are helpful to my learning," "My instructor treats all students with respect," "My instructor creates an atmosphere where ideas can be exchanged freely and easily"). All items were rated on a 5-point Likert scale, and Cronbach's alpha coefficient was .960.

To analyze discussion threads, this research used (1) SNA and (2) content analysis. SNA explains relationships with nodes and ties (or links) between nodes that have their own characteristics that can be categorized. For example, nodes can be people, organizations, or countries. The ties between the nodes indicate interactions and relationships. Researchers have proposed that SNA provides more in-depth information and new perspectives for analyzing the interactions and relationships of instructors or students by complementing the limitations of purely qualitative and quantitative measures (Jo et al., 2017; Long & Koehler, 2021; Yen et al., 2019). For the SNA in this study, a researcher read all the discussion postings and determined who talked to whom for each posting to identify who and whom relations. The following is an example of a posting demonstrating a who (Mike) and whom (Jim) relation between two students (the participants are anonymous for this study).

(Mike's posting)

Jim, your comment about having smaller blocks of texts made me wonder about how instructional designers could/should learn the "best practices" from graphic designers and other related fields to improve distance learning courses. Might there be other applicable "best practices," e.g., color selection, font choice, etc., that would improve a course?

Based on this analysis, I created an adjacency matrix in which the rows and columns represent who created a post for whom, respectively. Next, outdegree and indegree centrality were measured to identify instructors' positions in the network. Outdegree centrality indicates the degree of interaction that initiates from an actor, while indegree centrality means the degree of interaction that is directed toward an actor (Saqr et al., 2022). High outdegree centrality is likely to be a sign of students' active participation or contribution to the discourse. In contrast, high indegree centrality, which is computed as the number of received replies or comments, may be a reliable indicator of high popularity or prestige in the network (Saqr et al., 2022).

In addition, density, degree centralization, and reciprocity were calculated to analyze the student participation and interaction attributions of the online discussion networks in the novice and experienced instructor's courses. Density is a means to measure the number of connections formed within a network. It is calculated as the direct number of actual connections divided by the number of all possible direct connections in a network (Cheng et al., 2022). A higher density indicates that the network is likely to be a more cohesive community than another network with a lower density. Next, degree centralization, which refers to a network that concentrates on actors with high degree centrality, was calculated. The high outdegree centralization indicates that a few core members are creating most of the connections to others, while the high indegree centralization means the network is focused inward on a few core members (Goggings et al., 2016, p. 248). Finally, this research also calculated the reciprocity of the two discussion networks. High reciprocity means that people in the network tend to have more mutual and bilateral relations than a network with low reciprocity (Pfeil, & Zaphiris, 2009).

For content analysis, the discussion posts were analyzed using the four phases of cognitive presence. In addition, the instructors' postings were also analyzed using the same indicators to obtain more information about the qualitative nature of the two instructors' interactions in the discussion boards. Each message posted by instructors or students was treated as a unit of coding indicating one of the four phases of cognitive presence. For inter-rater reliability, this study adopted a consensus approach and percent agreement which is the most common reliability index for content analysis of online asynchronous discussions (De Wever et al., 2006; Sadaf & Olesova, 2017). The discussion postings were coded by two researchers including the primary researcher. Before beginning the coding process, the two researchers met to review the coding scheme. Next, we independently coded the instructor and student postings with the four levels of cognitive presence. We then thoroughly discussed and compared the results to clarify the understanding of the coding scheme and reach a consensus. After discussing the individual coding results, the researchers reached 100% inter-coder agreement.

For the survey data, descriptive statistics (mean and standard deviation) and a Mann-Whitney-Wilcoxon test were used to compare students' satisfaction and cognitive presence levels between the novice and experienced instructor sections. To analyze interaction attributions and network structures in discussion boards, this research used UCINET which is one of the most well-known social network programs. The NetDraw program was also used to generate a sociogram. For statistical analysis, this study used SPSS 26.

4. Results

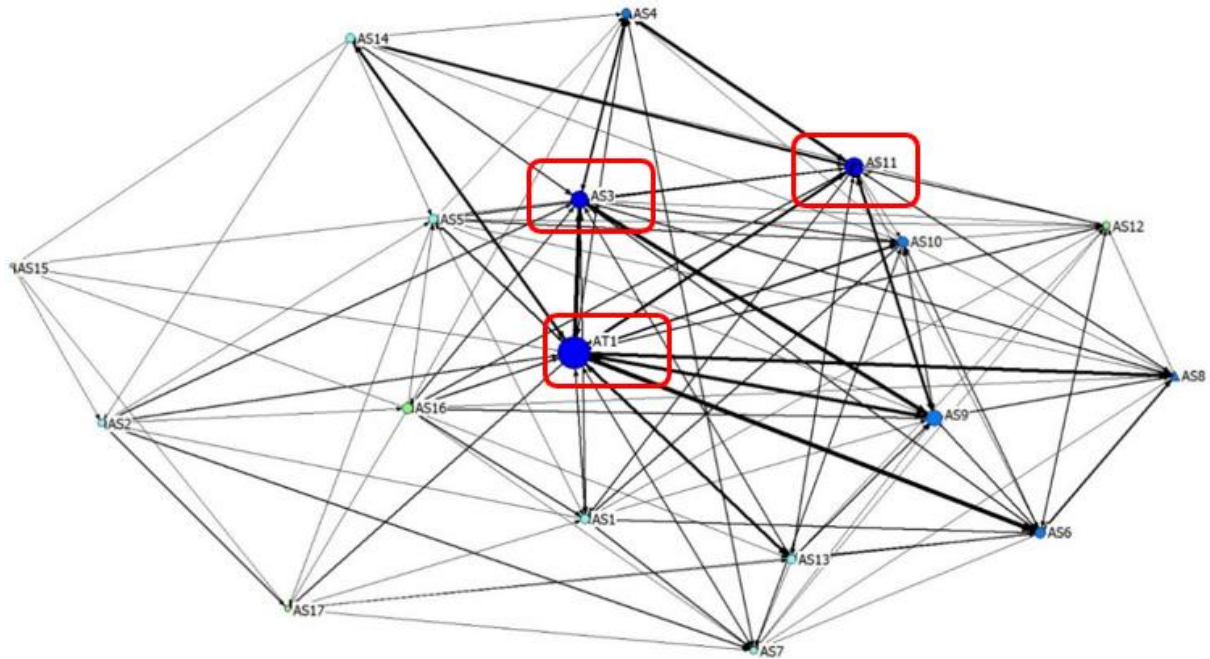
4.1. What were the patterns of a novice instructor's and an experienced instructor's interactions on the asynchronous discussion boards?

For RQ1, both SNA methods and content analysis of instructors' posts were used to explore interaction patterns of a novice and an experienced instructor on the discussion boards. First, according to the network maps for all weekly discussion postings from the two sections, it seemed that both instructors placed in the middle and each took a core role in their respective discussion network (see Figures 1 and 2). As the result of examining the indegree and outdegree centrality of each instructor, both instructors showed high centrality in their discussion network. However, there are some differences between the two groups. First, the experienced instructor (AT1) was the most active and central actor, while the novice instructor section had three students (BS2, BS5, and BS15) who showed higher centrality than the instructor (BT2). Next, the experienced instructor had a much higher outdegree centrality than indegree centrality, while novice instructor showed almost equal values for indegree and outdegree centrality. This implies that the experienced instructor was more eager to contact students and to actively initiate conversations with students than the novice instructor (see Table 1).

With the SNA, this research also explored the nature of instructors' postings qualitatively. To do this, the contents of both instructors' postings were analyzed with cognitive presence indicators. Specifically, I focused on instructors' postings from week 1 to week 7 discussion boards. All instructors' postings were either divided into one of four cognitive presence categories (triggering event, exploration, integration, resolution) or marked

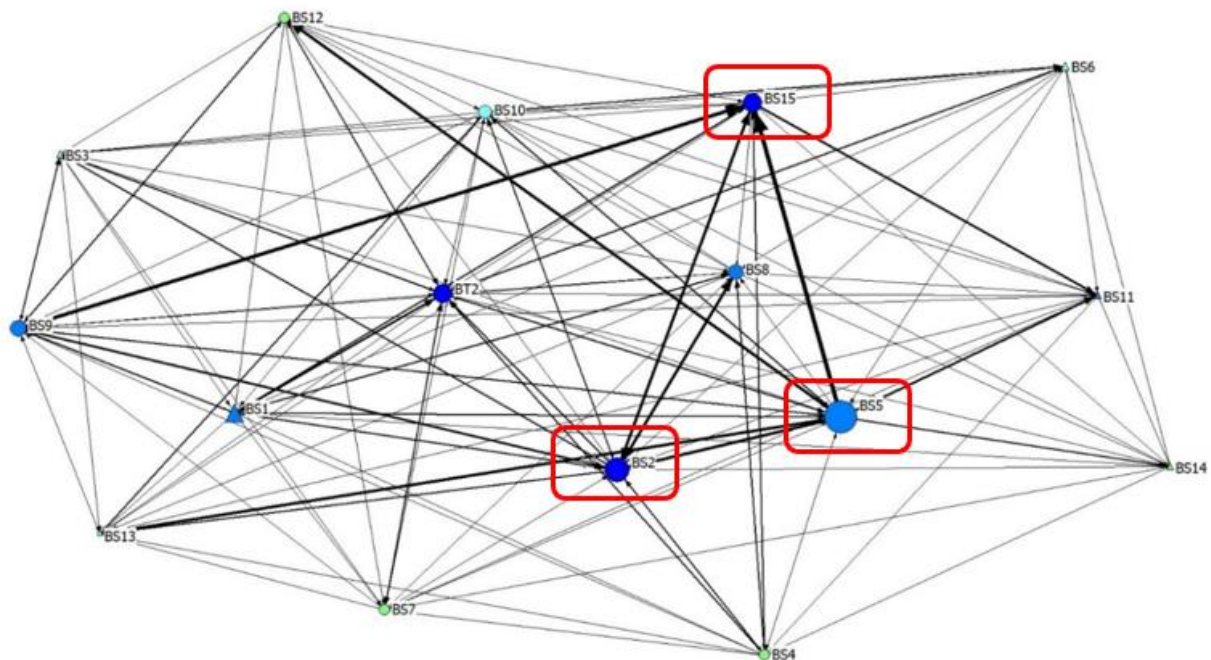
miscellaneous. Most of the experienced instructor's postings were concentrated on triggering events (36.92%) or exploration (46.15%). Triggering event (41.82%) had the highest rate of all four cognitive presence levels in the novice instructor's postings. Notably, the novice instructor showed more integration activities (25.45%), summarizing or synthesizing students' postings than exploration (18.18%) (See Table 2).

Figure 1. The network map for all discussion boards (except for week 4) in the experienced instructor section



Note. Node size by outdegree centrality; Node color darkness by indegree centrality; Circle-shaped node = female; Triangle-shaped node = male.

Figure 2. The network map for all discussion boards (except for week 4) in the novice instructor section



Note. Node size by outdegree centrality; Node color darkness by indegree centrality; Circle-shaped node = female; Triangle-shaped node = male.

Table 1. The indegree and outdegree centrality of each actor in the experienced and novice instructor sections

Experienced instructor section			Novice instructor section		
Actor	Indegree	Outdegree	Actor	Indegree	Outdegree
AT1	0.218	0.447	BS2	0.339	0.333
AS11	0.159	0.235	BS5	0.224	0.430
AS3	0.188	0.200	BS15	0.315	0.261
AS9	0.147	0.188	BT2	0.279	0.248
AS6	0.147	0.100	BS9	0.224	0.212
AS10	0.112	0.088	BS1	0.176	0.230
AS4	0.118	0.071	BS8	0.212	0.194
AS8	0.118	0.071	BS10	0.158	0.188
AS13	0.106	0.076	BS7	0.127	0.152
AS14	0.094	0.082	BS11	0.176	0.103
AS1	0.100	0.071	BS12	0.127	0.145
AS5	0.094	0.065	BS3	0.170	0.097
AS16	0.071	0.088	BS6	0.139	0.115
AS7	0.094	0.053	BS4	0.091	0.158
AS2	0.076	0.059	BS13	0.170	0.079
AS12	0.065	0.053	BS14	0.109	0.091
AS17	0.047	0.035			
AS15	0.035	0.006			

Table 2. Frequencies and percentage of instructor posts per cognitive presence subcategory

Instructor	Triggering event	Exploration	Integration	Resolution	Miscellaneous	Total
Experienced	24 (36.92%)	30 (46.15%)	6 (9.23%)	0 (0%)	5 (7.69%)	65 (100%)
Novice	23 (41.82%)	10 (18.18%)	14 (25.45%)	0 (0%)	8 (14.55%)	55 (100%)

4.2. What were the patterns of the student participation and interaction in the novice and experienced instructor facilitated discussion boards?

For RQ2, this research measured the quantitative data with SNA to analyze the patterns of discussion board networks in the two sections. First, the network in the novice instructor's section showed a higher mean degree than experienced instructor section. This implies that overall interactivity of participation in the novice instructor's section was higher than in the other instructor's section. In the case of density, the novice instructor's section showed a higher density than the experienced instructor's section. A higher density means that more students participated in the network. Table 3 shows more detailed information about the student participation and interaction patterns of the online discussion networks in the novice and experienced instructors' sections.

Table 3. Comparison of the discussion networks in the novice and experienced instructors' sections

Value	Experienced instructor section	Novice instructor section
Ave degree	7.294	10.400
Out-centralization	0.379	0.276
In-centralization	0.180	0.199
Density	0.456	0.743
Component	1	1
Reciprocity	0.645	0.859

As shown in the table, the novice instructor's section is considered a more active and closely connected network than the experienced instructor's section from higher density, although it is smaller discussion network ($n = 16$) than the discussion network in the experienced instructor section ($n = 18$). The network in the novice instructor's section also seems to have more mutual and stable relationships in that it shows high reciprocity. For centralization, the experienced instructor's section showed higher outdegree centralization than the other. This indicates that the network in the novice instructor's section tended to have more distributed power or interactions among discussion participants rather than being dominated by particular actors.

Moreover, the frequency and percentage of each cognitive presence level were examined for both sections to explore the students' postings qualitatively. Table 4 below illustrates the coding results for categories of cognitive presence. For both sections, integration had the highest rate of coded responses, followed next by exploration. Resolution had the lowest rate of all four levels of cognitive presence in both sections.

Table 4. Frequencies and percentages of student posts per cognitive presence subcategory

Instructor	Triggering event	Exploration	Integration	Resolution	Miscellaneous	Total
Experienced	16 (6.87%)	104 (43.64%)	109 (46.78%)	2 (0.86%)	2 (0.86%)	233 (100%)
Novice	29 (8.33%)	147 (38.89%)	190 (50.26%)	3 (0.79%)	9 (2.38%)	378 (100%)

4.3. How did cognitive presence level and satisfaction differ based on the interaction patterns of the novice and experienced online instructors?

To address RQ3, this research compared the levels for satisfaction and cognitive presence between two groups. Because of the small samples size, a Mann-Whitney-Wilcoxon test, which is a nonparametric statistical test, was used to explore any statistically significant differences between the novice and experienced instructors' sections in terms of students' satisfaction with discussion experiences and their cognitive presence levels. As a result, I found a significant difference in students' satisfaction levels between the experienced and novice instructors' courses ($Z = -3.057, p < .01$). Specifically, the students in the experienced instructor's section showed higher satisfaction than students in the novice instructor's section. However, this research did not find any significant difference in students' cognitive presence levels across sections ($Z = -.493, p > .05$) (See Table 5).

Table 5. Mann-Whitney-Wilcoxon test result on students' satisfaction and cognitive presence level

Variables	$M \pm SD$		Z	p
	Novice	Experienced		
Satisfaction	3.322 \pm 1.08	4.759 \pm 0.28	-3.057	.002
Cognitive Presence	2.469 \pm 0.29	2.415 \pm 0.17	-.493	.622

5. Discussion and implications

5.1. Analysis of instructors' facilitation and interaction patterns

This research explored an experienced and novice instructor's facilitation and interaction in online discussions with SNA and content analysis. As the result, the two instructors showed either similar or different patterns and characteristics in interaction. First, while the result of SNA revealed that both instructors are central and influential participants in discussion boards, the experienced instructor in this research played a slightly more central and active role than novice instructor. Considering instructor centrality as a means of measuring instructor control (Wang & Liu, 2020), the experienced instructor section was likely more instructor-led than the novice instructor section. For qualitative content analysis, both instructors posted triggering event messages frequently, asking questions to facilitate students to think the problems with new and in-depth perspectives. However, they showed somewhat differences in the exploration and integration activities. A majority of the experienced instructor's postings remained at the cognitive level of exploration (46.15 %), while the larger percentage of the novice instructor's messages (25.45%) remained at the integration level than exploration (18.18%).

Exploration is related to sharing information, providing different suggestions for consideration, brainstorming while integration is more related to the convergence of various ideas toward finding a solution (Garrison et al., 2001). The results of this research imply that the experienced instructor in this research focused on asking relevant questions to students in order to make them feel a sense of puzzlement, or on exchanging some information or ideas which students can consider. Contrary to this, the novice instructor in this research put more efforts toward synthesizing what students had discussed and toward creating solutions than exploration activities. Probably, considering the results of the qualitative content analysis, the novice instructor's section might be more instructor-centered in that the instructor took a more active and dominant role in knowledge construction through synthesizing or creating solutions him/herself, rather than guiding students to find their own solution.

While these results cannot be generalized to all novice and experienced instructors, they constitute an important reference for researchers and practitioners interested in finding effective methods for analyzing instructors' facilitation and interaction patterns. In this study, the experienced instructor appeared to take a dominant role in the discussion network, as he or she had the highest score for both outdegree and indegree centrality. However, the results of content analysis with cognitive presence indicators revealed further relevant details concerning the respective roles assumed by the two instructors. The experienced instructor was likely to play the role of facilitator or guide, concentrating on posing the relevant questions, providing supplemental resources or novel

viewpoints by triggering events or exploration activities. In contrast, the novice instructor was more concerned with synthesizing and constructing solutions for him/herself than the experienced instructor.

To summarize, this research suggests that patterns of instructor facilitation and interaction cannot be adequately assessed based on a single data set. It illuminates the importance of considering multiple datasets in order to ascertain whether online discussions are instructor-dominated or instructor-guided. Jo et al. (2017) have also contended that analyzing the centrality and density of a network may provide only limited information about the interactions within it, because these measures do not include analysis of the specific content of each posting on a discussion board. As they suggested, using qualitative content analysis as well as SNA would provide more in-depth information about students' interactions on discussion boards, given the ways in which the two methods complement each other.

5.2. Instructor centrality and student participation and interaction

The results of this research imply that frequent instructor participation or high prestige may not necessarily lead to active student participation and interaction. In this research, students in the experienced instructor's section, where the instructor showed the highest outdegree and indegree centrality, had lower density and less frequent discussion postings than students in the novice instructor section. Some previous research reported similar results about the relationship between the position or power of instructor and the participation rates or density of student interactions. For example, Fidalgo and Thormann (2012) demonstrated that students in a more instructor-centered network had lower density and participation rates in discussion boards than students in networks where the instructor shared his/her power with students. Ertmer and Koehler (2015) revealed that there was no relation between frequency of instructor postings and frequency of student postings. More recently, Wang and Liu (2020) identified that as the instructor centrality decreased, student's interaction density increased over the course duration. These results contradict to research showing that instructors' participation and facilitation are positively associated with students' engagement in discussions. Lee (2020) revealed that facilitator engagement has a significantly positive influence on the quality of students' discussion postings. Parks-Stamm et al. (2017) also revealed that instructor participation has significantly predictive effects on student participation in discussion boards.

The inconsistent results of previous research highlight the importance of keeping balance in the amount and power of instructor participation in discussion networks (Larson et al., 2019). Indeed, some researchers suggested that too much instructor participation may reduce the amount of student interaction and create over reliance on the instructor and thus overwhelm their abilities to interact with peers (Larson et al., 2019; Murphy & Fortner, 2014). Furthermore, it supports the necessity of considering the qualitative nature of instructor and student interactions in order to more deeply understand the attributes of discussion networks.

On the other hand, the inconsistencies in these results may be related to the class size of online discussions. Parks-Stamm et al. (2017) revealed that the relation between instructor participation and student engagement in discussions may vary depending on class size. They found that in small-sized online courses (less than 15 students), instructor participation contributes to increased student participation, whereas instructor participation does not impact student participation in medium classes (15–30 students). The present study confirms that frequent instructor participation does not guarantee active student participation and interaction. The result may be due to the fact that both courses in this study were medium size classes. The findings of previous and current research show that instructors and instructional designers should consider applying different interaction and facilitation strategies according to their course sizes.

5.3. Differences in students' cognitive presence levels and satisfaction based on instructors' interaction patterns

The results confirmed that there is a significant difference in students' satisfaction with the discussion experiences depending on the different interaction patterns between a novice and an experienced instructor. Importantly, the most distinguished difference between two sections was the two instructors' interaction patterns in asynchronous discussion boards while both sections shared the same course design, content, and structure. The results of this research allude that instructor interaction and facilitation activities play an important role contributing on student satisfaction even in the courses which have same course design and content.

Interestingly, in the experienced instructor's section, which showed higher levels of student satisfaction, the instructor participated in discussions more actively and frequently than the novice instructor. This may be

explained by previous research which found that students prefer instructor-led facilitation, because they expect their instructors to be effective moderators and subject matter experts who can improve their discussion (Hew, 2015; Hoey, 2017; Phirangee et al., 2016). Another factor which may explain students' higher satisfaction with their discussion experiences in the experienced instructor's section relates to actual and qualitative features of instructor facilitation styles, which were analyzed through content analysis. As stated above, the experienced instructor focused more on triggering events or exploration activities, whereas the novice instructor uploaded more integration postings than the experienced instructor, by synthesizing ideas or constructing solutions. Students may prefer instructors to ask questions to pique their curiosity or sense of puzzlement or to assist them in brainstorming new ideas, rather than directly offering solutions.

Notably, although the novice instructor section is more closed and stable network than the experienced instructor section, students' satisfaction with their discussion experiences is higher in the experienced instructor section than in the novice instructor section. The result of this research implies that more interaction in the asynchronous discussion boards may not guarantee higher student satisfactions with the discussion experiences. The similar results were confirmed by other research. An et al. (2009) reported that students' satisfaction with instructor and online course may not be correlated to their interaction level by confirming a group which had little interaction (with relatively low density, mean number of initial postings and replies) showed higher satisfaction than other groups which had more interactions. Lim (2023) did not observe any significant predictive effect between SNA interaction measures (outdegree and indegree centrality) and learning satisfaction. The results of previous and current research suggest that additional factors may be required to improve the effects of interactivity on satisfaction.

Regarding the cognitive presence level, there was no significant difference in students' cognitive presence level between the experienced and novice instructor section. While students in the novice instructor section showed more interaction and participation in the discussion boards, their cognitive presence levels did not have any difference from students in the experienced instructor section. The result corresponds to previous research indicating that student's social interaction does not guarantee their cognitive engagement (Liu et al., 2022; Ouyang & Chang, 2019).

Finally, for both sections in the current research, the largest percentage of messages was at integration level, which was followed by exploration. The result corresponds to the previous research which reported that the postings in the integration level were the highest percentage of all students' postings (Akyol & Garrison, 2011; Oh et al., 2018). Probably, this is because the same course design of two sections played a more critical role in developing students' cognitive presence than the distinguished patterns of instructor interaction. The discussion topics or questions in these studies might be more appropriate to lead students' response at the integration level. Similarly, several researchers confirmed that there are significant relations between question types and students' cognitive presence levels (Richardson et al., 2013; Sadaf & Olesova, 2017).

6. Limitations and future research

Although this study has resulted in valuable findings, it also has several limitations which are acknowledged. First, the present study only evaluated one experienced instructor and one novice online instructor with a small sample size of students. As a result, the findings of this research cannot be generalized to other experienced and novice instructors. Further research should be performed with larger participant samples from more diverse settings to identify more common interaction patterns of experienced and novice instructors. Second, the gender ratio of the students in this research is disproportionate between the sections which may have led to some differences in the learning outcome variables. Future research should ensure a balance between participants' genders. Also, it is possible that other characteristics of instructors (e.g., instructors' behaviors to improve students' social presence such as calling students by their first name, using humor, expressing agreement) may impact the study's results. Future research should consider the impacts of other teaching styles on students' cognitive and affective learning outcomes more closely.

Next, in this research, the current research explored the patterns of instructor and student interaction with their discussion postings. However, future research may need to investigate the intentions or purposes of instructor and student interaction by conducting interview with instructors and students. This is because instructors' pedagogical intention which are hide in frequency or outward nature of their interactions are likely to important in understanding their interaction patterns more in-depth. Students also may have undisclosed reasons or intentions for their interaction patterns. It would be good to explore the patterns of instructor and student interaction with varied datasets, including their interview for triangulation. The multiple dataset will allow a

more comprehensive understanding of the effects of instructor interaction patterns on students' interaction, satisfaction, or cognitive thinking abilities. Despite these limitations, the findings of this study will hopefully provide some insights for researchers and practitioners seeking a more in-depth and comprehensive understanding of instructor or student interaction and participation.

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Appendix. Levels and examples of cognitive presence indicators

Phase of cognitive presence	Indicator	Examples
Triggering events	<ul style="list-style-type: none"> Recognizing the problem Sense of puzzlement 	<ul style="list-style-type: none"> XXX, your comment about having smaller blocks of texts made me wonder about how instructional designers could/should learn the “best practices” from graphic designers and other related fields to improve distance learning courses. Might there be other applicable “best practices,” e.g., color selection, font choice, etc., that would improve a course?
Exploration	<ul style="list-style-type: none"> Divergence – within the online community Divergence – within a single message Information Exchange Suggestion for consideration Brainstorming Leaps to conclusions 	<ul style="list-style-type: none"> I’m not sure I agree with her black/white presentation that some people are concrete thinkers and others are abstract thinkers. I was thinking, your approach is more similar to neo-Fordist, not post-Fordist in my opinion, because like you stated, the class has a pre-defined syllabus and the learning theories and communicating methods are all assigned. There are some certain things that are designed for each individual (like project topics and such) but the main idea and path is all one. That sounds like neo-Fordism. What do you think? https://www.youtube.com/watch?v=f5X64QCDVnI Neil deGrasse Tyson gave a speech that has always made me smile. It discusses religion and doctors (the MD type, we love the PH.D and Ed.D types), so if you are religious or a doctor and don’t like it... sorry? If you watch the video, focus on the 2:14 mark. He makes a statement that could apply to our discussion and a result of mass produced education.
Integration	<ul style="list-style-type: none"> Convergence – among group members Convergence – within a single message Creating solutions Connecting ideas, synthesis 	<ul style="list-style-type: none"> Hi XXX I can see how the dated studies are relevant and do form a baseline to help the field advance. An example that comes to mind from the chapter was how Garrison discussed and used distance education technology. Garrison (1990) stated, “a description of audio teleconferencing was used to argue for an appropriate concentration on the role of the teacher and the importance of two-way communication in the education process.” That statement has advanced According to our text, a second study based on the work of Ross, Morrison, Smith and Cleveland (1991), “researchers concluded by emphasizing the importance of assessment of learner satisfaction to overall success of a distance education program” (2012, pg.70). Other studies illustrated in our text, showed a direct link between attrition and anxiety. According to research “anxiety felt by DE learners played a higher role in attrition than that previously considered” (2012, pg. 71). Based on these previous findings, motivation will play an important role in retention. By applying motivational factors that may minimize potential anxiety found within distance education (DE), students may be more willing to complete DE programs.
Resolution	<ul style="list-style-type: none"> Vicarious application to 	<ul style="list-style-type: none"> In the training I’m currently developing at work, there are a

	<p>real world</p> <ul style="list-style-type: none"> • Testing solutions • Defending solution 	<p>variety of learning objects that we are going to be utilizing (instructional videos, video examples, screen-capture modules, eLearnings, job aids, etc.). We are also in the process of designing and building an online learning portal to deliver these objects to learners. The portal design will incorporate background functionality to track the learners' progress, me to proficiency, number of _times they try to complete an "assignment", how long it takes them to complete it, how well they do in the completion of the assignment, what resources they use, what they use first/second/third, what they come back and reuse later, and so on and on. By tracking details this in-depth, we'll be able to determine which resources are the most beneficial to the assignment, which are most useful on the job, which hurt them in the completion of an assignment, which resources may not be clear enough, etc. An example might be that each learner watches the instructional video, but then immediately refer to the eLearning, which may indicate that the instructional video isn't helpful. Another example could be that learners use the screen capture to learn how to complete the assignment initially, but they refer back to the job-aid as a quick process check later when doing that function on the job. Or we may find that every learner who refers to a particular job aid fails the assignment the first time, but upon using a different learning object passes it the second _me. This could indicate a problem with that particular object, leading us to remove it and update it. While this level of tracking and analysis on the back end will help us study the effectiveness of learning objects, we'll also utilize pre- and post-tests along with L1-3 evaluations to determine the learner experience and the effectiveness of the training as a whole....</p>
Miscellaneous		<ul style="list-style-type: none"> • Great find XXX! Thanks for sharing with us! :)

Enhancing self-regulation via prompts and modeling in virtual flipped classroom

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ABSTRACT: This mixed method study aims to address the lack of self-regulation in primary school students through providing self-regulation training with prompts and modeling in virtual flipped classroom (VFC). A four-week training was integrated into an extra-curricular program of Chinese speech with prompts or modeling embedded in pre-class videos. The study examines to what extent and how prompts and modeling affect students' self-regulation and learning outcome. Forty-two primary school students from Grades 4 to 6 were randomly assigned into the prompt group and the modeling group. Both groups had not received self-regulation training before and did not show significant difference in the pre-test of self-regulation and the ability of speaking Chinese. The study collects multiple types of data including questionnaires, students' notes, observations, interviews, and speaking tests. The study is innovative as it directly compares the effectiveness of modeling and prompts on enhancing students' self-regulation. The results show that both prompts and modeling are effective in enhancing students' self-regulation and learning outcome with modeling having an edge over prompts. The students and their parents expressed positive views towards self-regulation training in the program. This study provides several implications for practitioners on how to cultivate students' self-regulation.

Keywords: Self-regulation, Prompts, Modeling, Flipped classroom

1. Introduction

Flipped classroom that combines online and face-to-face teaching becomes an increasingly popular mode of learning in the past decade (Akçayır & Akçayır, 2018). Empirical studies have reported that flipped classroom is more effective than traditional classroom at primary, secondary, and tertiary levels (e.g., Clark, 2015; Lai & Hwang, 2016; Lo & Hew, 2017; Unal & Unal, 2017; Wei et al., 2020; Yang & Chen, 2020). The virtual flipped classroom (VFC) mode is an emerging field that differs from the traditional flipped classroom in the in-class stage: traditional flipped classroom is conducted in-person whereas VFC adopts synchronous online meeting during in-class stage (Ismail & Abdulla, 2019; Jensen et al., 2018). The pre-class stage of the two modes are similar with students learn at home on their own (Akçayır & Akçayır, 2018). When learning takes place outside classroom, it puts higher demand for self-regulation on the part of students (Lai & Hwang, 2016). However, the lack of self-regulation is observed as a common problem when students learn in an online mode (Li & Zhou, 2021). Self-regulation has been generally recognized as vital for academic success and especially so in online learning (Barnard et al., 2009; Broadbent & Poon, 2015; Jansen et al., 2019; Sitzmann et al., 2011; Zimmerman, 2011). As such, there is a strong need to enhance students' self-regulation when implementing flipped classroom.

Direct training has been hailed as an effective measure for developing students' self-regulation and improving learning outcomes in online learning environment (Dignath & Büttner, 2008; Gentry et al., 2020; Theobald, 2021). This study sets out to tackle the lack of self-regulation of primary school students in a VFC mode through providing training of self-regulation. On account that self-regulation is a rather abstract concept for primary students, we embedded prompts and modeling into the educational videos to facilitate the training. Prompts are visual cues used in the self-regulation training to guide students in regulating their learning (Bannert & Reimann, 2012). Modeling involves a person or a virtual character demonstrating the desirable actions and thoughts (Bandura, 2012). Both prompts and modeling have been implemented in the previous studies to facilitate the training of self-regulation, yet no study, to our best knowledge, has compared their effectiveness. In this study, we explicitly embed prompts for self-regulation and the modeling of self-regulation into the pre-class videos in an effort to enhance students' self-reflection and compare the effectiveness of prompts and modeling.

2. Literature review

2.1. Traditional and virtual flipped classroom

In the past decade, traditional flipped classroom has attracted increasing research attention in various disciplines (e.g., Lo & Hew, 2017; Song & Kapur, 2017; Lee & Choi, 2019). Traditional flipped classroom usually involves pre-class and in-class stages. In the pre-class stage, students learn in an asynchronous mode on their own with various learning materials such as readings, videos or a combination of the two (Clark, 2015; Lee & Choi, 2019; Yang & Chen, 2020). Learning videos can be supplemented with quizzes for checking students' progress (Lee & Choi, 2019). The in-class stage is reserved for activities such as group work and individual practice (Bergmann & Sams, 2012; Clark, 2015; Jensen et al., 2015; Lage et al., 2000; Lin et al., 2021) that may contribute to active learning and collaboration among students (Akçayır & Akçayır, 2018; Bergmann & Sams, 2016; Clark, 2015; Hoshang et al., 2021).

VFC, as an integration of virtual classroom and flipped classroom, began to emerge in recent years (e.g., Ismail & Abdulla, 2019; Phillips & O'Flaherty, 2019). Similar to traditional flipped classroom, VFC also involves pre-class and in-class stages with the pre-class stage carried out in an asynchronous mode. Yet the in-class stage of VFC is held in a virtual classroom with the use of video conferencing for real-time communication (Ismail & Abdulla, 2019; Lervik et al., 2016). With the closure of schools during the COVID-19 pandemic, VFC has gained popularity. Studies have shown that teachers could blend a range of synchronous and asynchronous tools to facilitate student learning. For instance, Gopalan et al. (2021) provided students with guided reading and lecture videos as pre-class activities and implemented online assessments and group activities in breakout rooms when the class met online. Li and Zhou (2021) reported a case of VFC with structured components including preview before class, in-class discussion, and the assignment after class. To enhance student engagement, they designed various activities for the in-class stage such as group discussions in breakout rooms, group presentations and feedback. Moreover, the existing research work has reported mixed findings of VFC on learning outcomes. For example, Ismail and Abdulla (2019) reported significant knowledge gain in a quasi-experiment study of implementing VFC while Stöhr et al. (2020) showed no significant difference in learning outcomes between VFC and traditional teaching.

2.2. Self-regulated learning

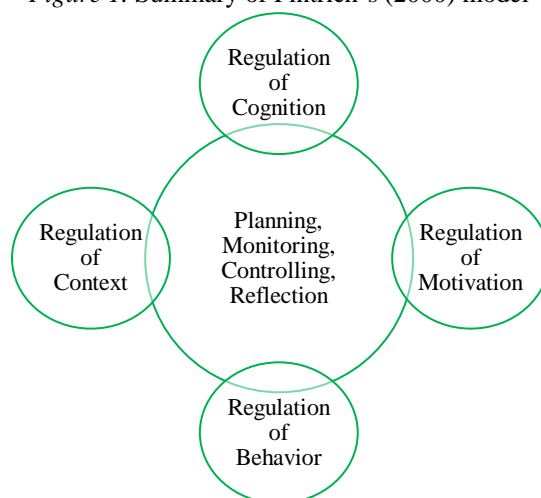
Scholars in the field of self-regulated learning have developed various models on the basis of different theoretical foundations. Irrespective of the different origins, the models of self-regulated learning share some characteristics. First, self-regulated learning is often viewed as a multi-dimensional concept encompassing the dimensions of cognition, motivation, context, and behavior (Pintrich, 2000; Zimmerman, 2013). Second, self-regulated learning has been conceptualized as a process involving different stages moving towards a goal (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 1998). Among different models, Pintrich's (2000) model was selected for the study due to its comprehensiveness in providing clear description of the stages and dimensions for self-regulation as described below.

Pintrich's (2000) model depicts four areas of self-regulation including cognition, behavior, context, and motivation. Each area can be regulated via four phases including planning, monitoring, controlling, and reflection (see Figure 1). Regulation of cognition involves cognitive planning, monitoring, controlling and reflection. Learners set learning goals, recall prior knowledge as well as strategies of self-regulation. They check their understanding, select appropriate learning strategies, and evaluate whether the goals have been met. Regulation of behavior includes behavioral planning, monitoring, controlling, and reflection. Learners plan their time and effort, decide whether or not to persist, adjust the effort spent in learning, and reflect on the decisions made. Regulation of motivation comprises motivational planning, monitoring, controlling, and reflection. Learners think about the value of learning, self-efficacy in learning, and the feelings of achieving goals. They become aware of the level of motivation and select strategies for keeping oneself motivated. Regulation of context comprises of contextual planning, monitoring, controlling, and reflection. Learners become aware of the contextual distraction, select strategies for improving the contexts or tasks, and evaluate the changed context.

Pintrich's (2000) model has been applied widely in the empirical studies concerning self-regulation. In the context of primary school, for example, Meier and Vogt (2015) examined the self-regulation of Grades 4 to 6 students during inquiry learning and reported evidences of cognitive planning, monitoring, controlling, and reflection. In a quantitative study, Kaya and Kablan (2013) denoted that self-regulation of Grade 4 students were

positively linked to the learning achievement. In our study, the four areas and stages of regulation in Pintrich's (2000) model guided the design of the self-regulation training for the students.

Figure 1. Summary of Pintrich's (2000) model



2.3. Training for self-regulated learning

The fundamental premise of this study is that self-regulation can be acquired through training. Training for self-regulated learning benefits students at different levels, from primary, secondary to university students (Dignath & Büttner, 2008; Dignath et al., 2008; Jansen et al., 2019; Theobald, 2021; Zheng, 2016). The current study focuses on two approaches – prompts and modeling since the previous studies have indicated their popularity and effectiveness for enhancing self-regulation (e.g., Moos & Bonde, 2016; Wijnia & Baars, 2021). These two methods are particularly suitable for VFC as they can be embedded in the videos for pre-class learning phase. However, they differ in the modality of presentation: prompts were presented in words and sounds, while modeling segments were presented through visual images and sounds. The comparison of them can shed lights on whether the modality of presentation leads to any differences in learning self-regulation.

2.3.1. Prompts

Self-regulatory prompts are cues specifically used to guide students to regulate their own learning (Bannert & Reimann, 2012). Empirical studies have used self-regulatory prompts in the form of questions, phrases as options, and statements as instructions (e.g., Lai & Hwang, 2016; Moos & Bonde, 2016; Müller & Seufert, 2018). Prompts have been widely used to foster self-regulated learning in traditional and online learning contexts (e.g., Daumiller & Dresel, 2019; Engelmann & Bannert, 2021; Ferreira et al., 2015; Müller & Seufert, 2018; Osborne et al., 2021; Schumacher & Ifenthaler, 2021; Sonnenberg & Bannert, 2019). However, some studies only involved the training of self-regulation in specific aspects. For example, Sonnenberg and Bannert (2019) embedded prompts focusing on cognitive regulation in online learning materials and reported that the group receiving prompts showed a higher frequency of cognitive monitoring of understanding.

There are only a few studies that explored the use of self-regulatory prompts in the flipped classroom mode. In the quasi-experimental study of Lai and Hwang (2016), primary students set goals in pre-class phase and the teacher clarified concepts during in-class phase followed by students' reflection on their learning after class. Their study shows that primary students receiving prompts on the regulation of cognition and time management had higher awareness of setting targets, using strategies and time planning. It indicated that the prompts were effective in raising the awareness of cognitive planning, cognitive controlling, and behavioural planning in Pintrich's (2000) model. Similarly, in the study of Moos and Bonde (2016), university students who received the prompts for cognitive regulation performed better in recalling prior knowledge, being aware of their understanding, and controlling their behaviours.

2.3.2. Modeling

Modeling is another useful means of enhancing self-regulated learning (Pintrich, 2000; Schunk, 1995; Kitsantas et al., 2000). Studies have shown that the positive effects of modeling self-regulatory strategies on students' regulation (Raaijmakers et al., 2018; Wijnia & Baars, 2021, Cleary & Zimmerman, 2004). Similar to the studies involving prompts, the studies using modeling also tend to focus on cognitive regulation. For instance, Raaijmakers et al. (2018) used video-based modeling for the demonstration of mathematical problem solving and reported that students successfully applied such skills in solving problems. When it comes to the context of flipped classroom, the studies of self-regulation training via modeling are even more scarce than those of prompts. In one of such studies, Wijnia and Baars (2021) provided video-based modeling of cognitive regulation for Dutch secondary students and showed that the students could apply the skills in solving biological problems.

2.4. Research gaps

On the whole, the existing work in relation to VFC is mostly contextualized in higher education with a dearth of empirical studies in primary school context. Additionally, the empirical studies on the implementation of VFC showed mixed findings. For example, Ismail and Abdulla (2019) reported significant difference in student learning in the VFC. However, Phillips and O'Flaherty (2019) compared one group learning through VFC with the other group in blended learning mode and noted little difference in learning between the two. Such mixed findings lead to the necessity of further exploring student learning in VFC. Second, the study that involved the training of self-regulation often concerned the regulation of cognition, motivation, behavior whereas the regulation of context is often neglected (Hensley et al., 2022). Third, considering that pedagogical design is crucial for the implementation of flipped classroom (Song et al., 2017), more research on pedagogical design of supporting self-regulation is necessary for successful implementation of flipped classroom. More importantly, there has not yet been studies comparing prompts and modeling in enhancing self-regulation in VFC.

3. Methods

3.1. The present study and research questions

The current study aims to foster self-regulation of primary students via prompts and modeling in virtual flipped-classroom. Pintrich's (2000) model of self-regulation is adopted as the theoretical framework to guide the design of the training and data analysis. Three research questions are posed to guide our study:

- To what extent and how do prompts and modeling affect primary students' regulation of cognition, behaviour, context, and motivation in VFC?
- Is there any difference in learning outcome of primary students receiving self-regulation training via prompts and modeling?
- What are the perceptions of students, their parents and the teacher on learning self-regulation using prompts and modeling in VFC?

3.2. Research design

Contextualized in a private primary school in Hong Kong, this study adopted an experimental mixed method research design. A four-week training on self-regulation was integrated into an extra-curricular program for the Chinese Speech Club by embedding prompts or modeling in learning videos for the pre-class phase. That is to say, the videos prepared for the pre-class stage included both lectures on learning content (Chinese speech) and self-regulation training. We recruited forty-two students from each level of upper primary section (P4, P5, P6) who joined the speech club. The participating students included 22 female and 20 male students between nine to eleven years old. The students were randomly assigned to two groups: the prompt group (FCP) and the modeling group (FCM). Each group had a similar composition of students with no prior training of self-regulation. The learning contents and structure of the training were the same for the two groups and both groups were taught by the same teacher who had 14 years' experience of teaching Chinese.

The self-regulation training included the same content which was designed as prompts and modeling videos for the two groups respectively. That is to say, the main difference between the prompts group and modeling group was the mode of presentation of self-regulation training: prompts of self-regulation were provided in text format whereas modeling videos involved the teacher demonstrating the self-regulation strategies (see Figure 2). Sixteen

videos (about ten minutes for each) were prepared, eight for each group. As shown in Table 1, the four aspects of self-regulation were introduced progressively in the training.

The content of each FCP video included prompts (including questions and options) designed based on Pintrich's (2000) model and the instructional videos on delivering speech. The videos were then uploaded to Edpuzzle and prompts were inserted at different places of the videos. The production of FCM videos was more complicated as additional modelling video was developed with the teacher modeling self-regulation while watching the sample lesson. The preparation work included scenario brainstorming, scene setting and prop preparation. The scenario and the scene were developed based on Pintrich's (2000) model and the strategies demonstrated echoed with the prompts provided for FCP group. The finished video for FCM group was also uploaded to the platform of Edpuzzle.

Figure 2. An example of prompts and modeling of regulating context


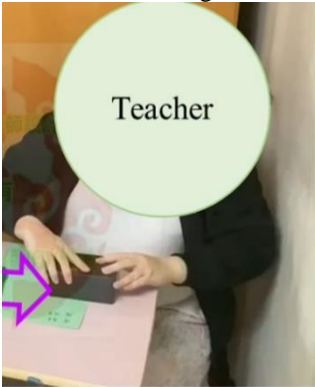
Prompts	Modeling
 <p style="text-align: center;">Translation:</p> <p>How can I change my learning environment to make myself to be more attentive?</p> <p><input type="checkbox"/> Remove toys / Tidy the desk</p> <p><input type="checkbox"/> Go to a quiet / comfortable place to study</p> <p><input type="checkbox"/> Switch off the television / other audio equipment</p>	 <p style="text-align: center;">Description:</p> <p>The teacher stopped playing with the toys on the desk. She opened the box, put the toys into it and then covered it.</p>

Table 1. Progression of integrating self-regulation

	New aspect added
Lesson 1 and Lesson 2	Regulation of cognition
Lesson 3 and Lesson 4	Regulation of behavior
Lesson 5	Regulation of context
Lesson 6	Regulation of motivation
Lesson 7-8	(All aspects included)

3.3. Instruments and data collection

In the current study, mixed methods were used to collect various data including questionnaires, speaking tests, lesson observation, interviews, and students' notes (see Table 2). The effects of self-regulation training on students' learning and self-regulation were measured through pre- and post-questionnaires before and after the four-week program. We adapted the shortened version of Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & DeGroot, 1990) to measure the level of self-regulation. Behavior and study environment regulation from the original version were added to the shortened version. Apart from individual aspects, the self-regulation scale measured self-regulation as a whole. The reliability tests of the self-regulation scale including use of cognitive strategies (regulation of cognition), behaviour (regulation of behaviour), study environment (regulation of context), intrinsic value and self-efficacy (regulating motivation), and overall self-regulation yielded the results from 0.708 to 0.827. Additionally, the questions were added to the questionnaire to collect students' opinions. An example of the questionnaire items is "I have a regular place set aside for studying". Speaking tests were conducted at the beginning and upon the completion of the program to measure students' learning outcome. In the pre- and post-speaking tests, students were required to give a two-minute speech with the script provided. They were assessed based on the content covered in the course including the application of stress and pausing for delivering a clear message and non-verbal communication like eye contact, facial expression, hand gestures and posture. Each item was rated based on a four-point grade level. The values of Cronbach's alphas for delivering a clear message and non-verbal communication were 0.971 and 0.830.

Table 2. Summary of data collection

Measurement	Self-regulated learning	Speaking	Perception
Notes	✓		
Speaking test		✓	
Questionnaire	✓		✓
Lesson observation	✓		
Interview	✓		✓

During the synchronous class through Zoom, the students were expected to apply the self-regulation strategies acquired in the training. All the synchronous online classes were observed via Zoom in order to examine whether the students could apply the self-regulation strategies. One teacher with 12 years of teaching experience joined the researcher in the observation. The observation form was compiled with a list of possible indicators of regulation grouped into four areas of Pintrich's (2000) model. For example, the indicators for the regulation of context included wearing earphones, asking siblings to go away. The form was completed at a five-minute interval during the observation. The inter-rater agreement for Lesson 1 and Lesson 8 is 81% and 85%. The average frequency of each item was calculated for comparison. In addition, the students voluntarily took notes during the course without unified format and took photos of their notes for submission.

Interviews were conducted with all the students, their parents and the teacher after the program. Individual semi-structured interviews were conducted with 42 students and their parents to have a better understanding of their perceptions of the training. Some sample questions are: "What do you think about learning self-regulated learning in flipped classroom used in this course? Why?", "What do you think about using modeling (for FCM group) / prompts (for FCP group) in videos to learn self-regulated learning? Why?", and "In videos, the teacher took on the role of a child to learn. What do you think about it? Why?" (for FCM group). To elicit the students' opinions, three questionnaire items were added at the end of the post-questionnaire including (1) "I am satisfied with the speaking course"; (2) "I like the mode of learning in the course (online flipped classroom)"; (3) "I think demonstration in videos can help me learn self-regulated learning" for the FCM group and "I think prompts in videos can help me learn self-regulated learning" for the FCP group.

3.4. Data analysis

When analyzing quantitative data, Quade's test and Wilcoxon signed rank test were conducted due to two reasons. First, the data were not normally distributed, making non-parametric tests suitable. Second, as this study aims to examine individual aspects of self-regulation including regulation of cognition, motivation, context, and behaviour, univariate analysis is suitable for studying various aspects separately (Huberty & Morris, 1989). For the qualitative data, top-down and bottom-up approaches were used for thematic analysis of interviews and content analysis of the students' notes. Pintrich's (2000) model provided the basis for data analysis which helped the integration and comparison of data collected via different means. With the bottom-up approach, new insights and themes emerged from the data could supplement the model. In other words, most codes were derived from Pintrich's (2000) model with codes emerged from data added in through iterative thematic analysis. Table 3 shows the coding list for the regulation of cognition.

For observation data, the average frequency of each item was calculated for comparison in an effort to detect the pattern of students' self-regulation behavior. One tenth of the notes were analysed twice within a week with a percentage agreement of 92%. Additionally, two other experienced teachers were involved in data collection and evaluation which enhanced the reliability and validity of the data.

Table 3. Coding list for regulation of cognition

Codes	Indicators	Example
Subcategory: Cognitive planning		
Setting goals for learning Chinese	Students write the Chinese topic they expect to learn.	(a) I expect to learn stress and pausing. (b) Stress and Pausing
Setting goals for learning SRL	Students write the aspects of self-regulated learning they expect to learn.	(a) I expect to learn self-regulated learning (cognition). (b) Self-Regulated Learning – Cognition
Activating prior knowledge	Students write what they know about Chinese speech.	Prior knowledge: -Eye contact -hand gestures

Activating prior SRL knowledge	Students write what they know about SRL.	Skills learnt: (timeline)
Subcategory: Cognitive monitoring		
Monitoring cognition	Students clearly show that they understand the content either by adding ticks or expressing in words.	(a) Pronunciation – Read every word clearly. ✓ (b) Understand
Subcategory: Cognitive controlling		
Listing	Students list all the key words one after another.	Common hand gestures for public speaking - A palm - Both palms - Fingers - A fist
Dividing knowledge into different levels	Students highlight, underline, or add a symbol to important information.	(a) Meeting at work (b) Functions of Hand Gestures (c) * Expository Speech
Summarizing lecture by rephrasing	Students express what's learned in their own words.	(a) To sum up, don't use hand gestures in a strange way. (b) Quiet (soft but audible)
Self-questioning on Chinese content	Students question themselves on Chinese content. They either write personal questions, write impersonal questions or write new examples which implies questioning themselves to provide more examples.	(a) What other body language should I use? (b) What is delivering a speech? (c) "gwong" "gong"
Organizing ideas using graphic organizers	Students integrate key words together by using graphic organizers like tree diagrams, mind maps and tables.	A mind map.
Using pictures	Students draw pictures to supplement the words written.	Students drew a head with arrows to show direction of turning head.
Subcategory: Cognitive reflection		
Reflecting on cognition	Students reflect on what they learnt at the end and write their reflection in sentences or phases.	(a) I have learnt: The use of stress in giving a speech (b) Summary: Learnt ways of relieving myself to lower nervousness (c) Eye contact and facial expression

4. Results

This study focuses on exploring and comparing the effectiveness of prompts and modeling on primary school students' self-regulation and learning outcome. The results are based on questionnaires, students' notes, lesson observation, interviews and speaking tests.

4.1. Effects of prompts and modeling on self-regulation and learning

First, we examined and compared the effects of self-regulatory training involving modeling and prompts on students' self-regulation by comparing the pre- and post-questionnaire data. As to overall self-regulation, the results of Wilcoxon signed rank test show a significant rise in the prompt group ($Z = -4.019, p < .001$) as well as the modeling group ($Z = -4.020, p < .001$). By controlling pre-test score, Quade's test results show a significant difference between the two groups ($F(1, 40) = 20.335, p < .001$) with a large effect size (*partial eta square* = 0.337) indicating a larger increase in FCM group ($Mdn = 6.13$) than FCP group ($Mdn = 5.50$).

A similar pattern was observed when we looked into the four areas of self-regulation including cognition, behavior, context, and motivation. With regard to cognitive regulation, Wilcoxon signed rank test indicates a significant rise in FCP group ($Z = -3.923, p < .001$) and FCM group ($Z = -4.017, p < .001$). Quade's test shows a significant difference between the two groups ($F(1, 40) = 17.862, p < .001$), with a larger increase in FCM group ($Mdn = 6.00$) than FCP group ($Mdn = 5.250$). As to behavioral regulation, a significant rise is noted for FCP group ($Z = -3.930, p < .001$) as well as FCM group ($Z = -4.020, p < .001$) upon conducting Wilcoxon signed

rank test. Quade's test also indicates a significant difference between the two groups ($F(1,40) = 6.421, p < .05$), with FCM group ($Mdn = 5.75$) showing a higher increase than FCP group ($Mdn = 5.50$).

In terms of regulation of motivation, we measured intrinsic value and self-efficacy as the sub-items and noted the improvement in both for two groups of students. A significant rise is noted in intrinsic value for FCP group ($Z = -2.511, p < .05$) as well as FCM group ($Z = -3.140, p < .01$). Yet, there is no significant difference between the two groups ($F(1, 40) = 0.020, p > 0.5$). As to self-efficacy, the similar increment is observed for FCP group ($Z = -2.908, p < .01$) as well as FCM group ($Z = -4.017, p < .001$). A significant difference is also noted between the two ($F(1, 40) = 14.042, p < .01$) with FCM group ($Mdn = 5.00$) showing larger improvement than FCP group ($Mdn = 4.86$). As to the regulation of context, the results from Wilcoxon signed rank test shows a significant increase in FCP group ($Z = -3.528, p < .001$) as well as FCM group ($Z = -3.930, p < .001$) with a large effect size ($r = -0.544$). Again, Quade's test shows a significant difference ($F(1, 40) = 17.185, p < .001$) between FCP group ($Mdn = 5.667$) and FCM group ($Mdn = 6.333$), which indicates that FCM group outperformed FCP group in the regulation of context. To summarize, both prompts and modeling are effective in enhancing the overall and individual aspects of self-regulation. Modeling is more effective in enhancing self-regulation as compared to prompts in overall self-regulation and regulation of cognition, behavior, context and motivation measured in term of self-efficacy.

We also examined the effects of treatments on learning outcome through the pre- and post-speaking tests before and after the program. A significant rise was noted in the prompt group ($Z = -4.019, p < .001$) and the modeling group ($Z = -4.019, p < .001$). In addition, Quade's test was conducted to find the variation between the two groups. Having controlled the pre-test score, a significant variation was noted between prompts ($Mdn = 85$) and modeling ($Mdn = 93.00$) groups ($F(1, 40) = 10.042, p < .01$). In short, the modeling group outperformed the prompt group in both self-regulation and learning outcome.

4.2. Process of self-regulation

Other than the effects of self-regulation training, we also scrutinized how students regulated their learning in virtual classroom with the help of prompts or modeling videos. The rich data from interviews, students' notes, and observation provide a detailed account of the regulation of cognitive, behavior, context, and motivation.

4.2.1. Regulation of cognition

We collected and analyzed 179 sets of notes from the pre-class stage and 78 sets from in-class stage. First, more students from FCM group took notes during pre-class (70 from FCP and 109 from FCM) and in-class stages (28 from FCP and 50 from FCM). The content analysis of notes revealed the signs of cognitive regulation in all the aspects including cognitive planning, monitoring, controlling, and reflection with cognitive controlling as the most frequent and cognitive monitoring as the least frequent aspect. For cognitive monitoring and reflection, there is a higher frequency in FCM group than FCP group.

Table 4. Cognitive planning in pre-class and in-class notes

Cognitive planning	Frequency (%)			
	Pre-class Notes (Total = 179)		In-class Notes (Total = 78)	
	FCP group	FCM group	FCP group	FCM group
Setting goals for learning Chinese	24%	64%	32%	36%
Setting goals for learning SRL	31%	67%	0%	0%
Activating prior Chinese knowledge	11%	49%	0%	0%
Activating prior SRL knowledge	11%	39%	0%	0%

Table 4 shows the frequency of different strategies of cognitive planning shown in students' notes. During the pre-class stage, the frequency of all items (setting goals for learning Chinese speech, setting goals for learning SRL, activating prior knowledge, and activating prior SRL knowledge) is higher in FCM group than FCP group. For the in-class stage, FCM group also showed a higher frequency of goal setting for learning Chinese speech than FCP group. These suggest that both groups were able to apply goal setting and FCM group was more successful in learning and applying cognitive planning. Both groups showed no sign of setting goals and activating prior knowledge for self-regulated learning for in-class sessions. Possible reasons might be that students learnt self-regulation in pre-class videos only and did not expect to learn new self-regulation skills

during in-class sessions. There were no signs for activating prior knowledge of delivering speech as the students might have thought that they had activated such knowledge in pre-class sessions.

Table 5. Cognitive controlling in pre-class and in-class notes

Cognitive control	Frequency (%)			
	Pre-class Notes (Total = 179)		In-class Notes (Total = 78)	
	FCP group	FCM group	FCP group	FCM group
Listing	77%	72%	64%	54%
Dividing knowledge into different levels	0%	34%	11%	14%
Summarizing lectures by rephrasing	13%	57%	25%	52%
Asking questions	21%	35%	21%	26%
Organizing ideas using graphic organizers	21%	35%	29%	48%

Table 5 shows the frequency of cognitive control (e.g., listing key ideas, summarizing, organizing ideas using graphic organizers) noted in pre-class and in-class notes. Most often, the students took notes of the key points and both groups showed a similar level of frequency. However, FCM group shows a higher frequency of more advanced skills (e.g., highlight, summarizing, self-questioning, and creating graphic organizers) than FCP group. A possible reason might be that FCM group were more confident in applying more advanced skills after watching modeling videos.

During the individual interviews, the students also acknowledged cognitive controlling as the most useful strategies. The students believed that taking notes helped them remember what they learnt more easily. Additionally, they could review their notes to gain a deeper understanding as Student 40 commented: “After taking notes, I read it several times. Hence, I had a clearer understanding.”

4.2.2. Regulation of behavior

The individual interviews with the students provided rich and detailed description of how they use behavioral regulation including behavioral planning, monitoring, and controlling. First, behavioral controlling was the most useful strategies and many students believed that timetable was important as they could see clearly what they needed to do. For example, Student 32 commented: “It (timetable) made me know what I could do. So I will not ... get confused and distracted.” Additionally, they believed that planning and monitoring time was crucial for the effective use of time. Furthermore, the students regarded maintaining persistence, mainly through self-talk, as one of the most useful strategies that they frequently used. Student 3 described such instance as “I told myself to persist for five more minutes.” In consistent with the questionnaire data, the content analysis of notes taken in pre-class and in-class phases shows the signs of regulation of behavior like creating timetable and ticking completed tasks. The occurrence of behavioral planning and behavioral monitoring is higher in FCM notes than FCP notes.

4.2.3. Regulation of context

The interview data provided more detailed account of how students regulated their learning context. Among the strategies for regulating context, contextual monitoring and contextual controlling were the most useful ones that they frequently implemented. For example, Student 9 reported: “When I was in a noisy context, I could not hear my teacher. I missed some notes and could not focus.” Student 12 also mentioned: “I went to a place without so much noise.” Furthermore, the observation data showed the enhancement in regulating context for both groups during in-class learning. There is a decreasing trend in the frequency of looking around, talking to family members, playing with things, having background noise and family members walking by. Consistent with the questionnaire data, the decrease is more salient in FCM group which may imply the better regulation of context on the part of FCM group.

4.2.4. Regulation of motivation

The individual interviews with the students provide more concrete description of most useful strategies for regulating motivation like rewards and self-talk. An example of rewards for extrinsic motivation is mentioned by Student 38: “After the Zoom lesson, I could have a candy. As I wanted to eat a candy, I kept focused.” Student 20 provided an example of self-talk for intrinsic motivation: “I told myself, ‘After watching the video, I can learn

a lot.' ” Student 10 gave another example of using self-talk as a means of motivating oneself to maintain persistence: “I would say something encouraging like ‘Add oil (a Hong Kong English expression for encouragement)!’ I must not give up!” Furthermore, the content analysis of notes showed the evidence of motivational control through rewarding stickers which was more frequent in FCM group than FCP group.

4.3. Perceptions

We also looked into the perceptions of students, parents and the teacher regarding the self-regulatory training. Concerning the perceptions of students, the questionnaire results showed that both FCP and FCM groups were satisfied with their learning in VFC. Although FCM group ($Mdn = 7.00$) rated higher than FCP group ($Mdn = 6.00$) in course satisfaction and the usefulness of intervention, no significant difference was noted between the groups in course satisfaction, preference of VFC, and the usefulness of prompts or modeling. Aligning with the results of the questionnaire, students expressed positive opinions on the two methods in interviews. Student 23 denoted the function of prompts as such: “The questions reminded me to apply self-regulation.” Student 31 expressed the advantage of modelling as such: “The teacher took on our role. It made me understand more easily.”

The parents also showed support to the use of prompts and modeling in VFC. Parent 41 mentioned the importance of prompts as such: “Questions for regulation in the middle can lead students to the path that the teacher wants them to take.” Parent 32 described the advantage of roleplaying in modeling using a metaphor: “Actually, the teacher’s roleplaying is like a mirror... If the teacher does not use the students’ angle, ... the student may not be able to feel the same.” Similarly, Parent 21 mentioned her positive viewpoint on teacher-in-role: “The teacher acted it out, which is really good. The teacher is a special actor; they really can remember and follow her.”

The teacher in charge also expressed positive viewpoints on the two methods in use. In particular, she noted the values of the prompts as such: “The options gave them the ideas of what they could do at different stages.” She also expressed the advantages of teacher’s roleplaying in modeling: “Children usually think that teachers are experts in particular areas. I think this makes them be willing to follow me to try self-regulated learning. If their schoolmates acted it out, this might not be so persuasive to them.”

5. Discussion

In this study, we aimed to improve primary students’ self-regulation ability through implementing the training of self-regulation in virtual flipped-classroom context through integrating prompts and modeling into the instructional videos for the pre-class stage. The results indicate that both prompts and modeling can enhance students’ self-regulation with modeling outperforming prompts in both pre-class and in-class stages.

5.1. Effectiveness of prompts in enhancing self-regulation

The prompts embedded in the videos served as an effective reminder for students in regulating cognition, behavior, motivation, and context during online learning. Our findings support the previous studies showing the positive effects of prompts on regulating cognition (Ferreira, et al., 2015; Lai & Hwang, 2016; Sonnenberg & Bannert, 2019) and behavior in term of time planning (Fung et al., 2019; Lai & Hwang, 2016; Wong et al., 2021). Meanwhile, we also found the positive effects of prompts on regulating behavior which differs from the study of Moos and Bonde (2016) that reported no signs of monitoring time. The possible reason for the variation in findings might be that the prompts provided by Moos and Bonde (2016) did not target for regulating behavior while our study targeted all four aspects of self-regulation. This suggests that the prompts for regulating different aspects are needed for successful regulation of varied aspects. Apart from the regulation of cognition and behavior, our study provides solid evidence on the effects of prompts on enhancing regulation of motivation and context, filling the gaps in the existing studies regarding the regulation of context (Hensley et al., 2022).

Our findings also provide insights on how prompts help students regulate their learning. First, prompts as questions could remind students to self-regulate, which adds support to the use of prompts for activating strategies (Bannert & Reimann, 2012). Second, suggestions for regulation were included in the prompts in the form of options. This supports the function of prompts in providing directive functions (Wong et al., 2021). The

students of this study expressed that there were times that they did not know how to regulate and the options provided them with the guidance.

5.2. Modeling as a more effective means for enhancing self-regulation

More importantly, the study compares prompts and modeling in their effectiveness in enhancing self-regulation of primary school students. The most note-worthy finding is that modeling is more effective than prompts. There are several reasons that can explain why video-based modeling worked better. First, unlike prompts that are in the forms of written and spoken texts, modeling videos provide richer modality including images and sounds for vivid demonstration. As such, the students could visualize and rehearse self-regulation before the actual application (Bandura, 1986). The actions of observing and emulating the models lead to better internalisation (Schunk & Zimmerman, 2007), which then contributes to better self-regulation.

Second, the demonstration by modeling made the abstract concept of self-regulation more explicit as the students were able to observe the modeled actions and hear verbalized thoughts. Enhanced explicitness facilitated the encoding of new information about self-regulated learning, thereby contributing to the understanding and self-efficacy in relation to self-regulation. All these resulted in an increased willingness to apply self-regulatory strategies since self-regulatory efficacy is related to the willingness to regulate oneself (Bandura, 1986).

Third, the use of teacher role-playing a student in the modeling video also fostered the acceptance of targeted strategies. Such a design was well received by the students as well as parents who thought that it helped develop a sense of kinship. This can be explained by model-observer similarity hypothesis that maintains that the more similar learners perceived the model to be, the more likely they would be influenced and follow suit (Bandura, 1994). All these factors help to explain why modeling is more effective in cultivating self-regulation of students.

5.3. Effects of prompts and modeling on enhancing learning outcome

This study also examined how the training of self-regulation with prompts and modeling affect the learning performance of primary school students in a Chinese speech club. To this end, we measured students' abilities of giving a Chinese speech before and after the program and the students in both prompts and modeling groups showed significant improvement. The positive effect of prompts on learning outcome supports prior studies in online learning and flipped classroom (e.g., Daumiller & Dresel, 2019; Lai & Hwang, 2016; Moos & Bonde, 2016; Müller & Seufert, 2018; Schnauber & Bodemer, 2017; Sonnerberg & Bannert, 2019). Meanwhile, modeling also has the positive effect on learning outcome which aligns with prior studies (Gierlach & Washburn, 2018; Raaijmakers et al., 2018; Rodríguez-Málaga et al, 2021; Wijnia & Baars, 2021).

More importantly, modeling group showed greater improvement than prompts group in their ability of giving a Chinese speech. This might be related to the fact that modeling enhances self-regulation to a greater extent when compared with the prompt group. As self-regulation is positively linked to academic achievement (Zimmerman & Schunk, 2011), it is not surprising that the students in the modeling group also show greater improvement in the learning outcome.

Second, our study is contextualized in VFC mode. An issue of transfer is involved as the self-regulatory training was delivered through videos during the pre-class stage, and we examined students' self-regulatory behavior in both pre-class and in-class stages. To the best of our knowledge, there has not been research examining the transfer of self-regulation in different modes of online learning. Our data indicates that self-regulation can be transferred in two phases within VFC. The students gradually regulated their cognition, behavior, context and motivation not only in asynchronous online learning, but also in synchronous online learning.

6. Conclusion

This study is innovative as it directly compares the effectiveness of modeling and prompts and points out the comparative advantage of modeling in fostering self-regulation as well as students' learning. The results show that both prompts and modeling could enhance the regulation of cognition, behavior, context and motivation and the self-regulated strategies can be transferred from the pre-class to in-class stage of VFC. The students, their parents and the teacher showed positive opinions towards the training of self-regulation in VFC. Notwithstanding the contributions, the study has several limitations. First, it focuses on solving the problem of students' learning

in an extra-curricular program. Caution should be exercised when generalizing the findings to other learning contexts as students might react to the self-regulation training differently when in a regular class. Additionally, the intervention was implemented in the primary level only. It is plausible that prompts and modelling might have different effects on older students such as those in secondary school or university.

The findings of our study give rise to several implications for researchers and educators. There are several directions for future research such as the implementation of similar training to formal regular classes, in secondary or tertiary levels. More importantly, our findings generate several recommendations for educators on how to develop students' self-regulation. First, modeling is recommended and educators can also role-play a student so as to develop a sense of similarity and closeness. The self-regulatory training can be combined with asynchronous online learning tasks as students need self-regulation to tackle these tasks. Yet, teachers need to reserve sufficient time for producing the modelling video. When time is a concern, they can add prompts in the instructional videos. Prompts can be in the forms of multiple-choice questions that remind students to self-regulate. As the online learning is becoming a new normal in schools at all levels, we expect that self-regulation will become increasingly important. The self-regulation in different modes of online and blended learning will be a rich terrain for further exploration.

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Designing a self-regulated flipped learning approach to promote students' science learning performance

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ABSTRACT: Flipped learning, a well-established method in science education, sees its impact further amplified when coupled with the active control of self-regulated learners over their learning and metacognitive processes. In this study, a self-regulated flipped learning approach was designed and tested with the intention of enhancing the science learning performance of middle school students. A quasi-experimental design was employed involving middle school students from a science course in Turkey, with the aim to examine the impacts of the approach on students' academic achievements, attitudes, self-regulation levels, and motivations. The experimental group consisted of 29 students (14 male, 15 female) in the self-regulated flipped class, while the control group comprised 30 students (13 male, 17 female) who received traditional flipped learning instruction. In total, 59 eighth-grade students participated in the four-week study. Data were collected through achievement tests, attitude scales, self-regulated learning scales, and motivation scales. The results reveal that the experimental group outperformed the control group in terms of academic achievement, attitudes, self-regulated learning, and motivation. These findings can provide valuable insights and practical implications for educators and researchers in the fields of educational technology and science education.

Keywords: Self-regulated learning, Flipped learning, Science education, Middle school students

1. Introduction

Flipped learning (FL) represents an innovative pedagogical strategy that restructures conventional teaching paradigms by shifting direct instruction to outside the classroom and dedicating class time to active learning and problem-solving activities (Johnson & Renner, 2012). In recent years, FL has been acclaimed for its efficacy in augmenting learning outcomes (Bergmann & Sams, 2012; Kazeminia et al., 2022; Nja et al., 2022). By allowing students to delve into course content at their preferred pace prior to class, FL cultivates a student-centric environment that promotes collaboration and critical thinking (Chen et al., 2022; Tucker, 2012). Self-regulated learning (SRL) is an imperative educational construct that embodies the process wherein students actively govern their cognition, learning behaviors, and motivation (Panadero, 2017; van Alten et al., 2020a). By engaging in SRL, students can gain a deeper comprehension of intricate subjects and proficiently navigate challenges (Järvelä et al., 2015). This method encourages learners to set individual objectives, devise their learning strategies, monitor progress, and recalibrate their efforts as needed (Zimmerman, 2002). As the requirements of the 21st-century workforce continue to transform, fostering SRL in educational settings can equip students with vital skills that extend beyond the classroom, thereby preparing them for an ever-changing world.

The amalgamation of these two strategies within a self-regulated flipped learning (SRFL) framework can amplify students' learning experiences and outcomes by fostering autonomy and encouraging active participation in the learning process (Lai & Hwang, 2016). The integration of SRL within the FL approach can further enhance its efficacy by enabling students to take control of their learning processes and cultivate essential metacognitive skills (Kim et al., 2021; Jung et al., 2022; Silverajah et al., 2022; van Alten et al., 2020a; Yoon et al., 2021). This symbiosis between FL and SRL not only boosts learning outcomes but also heightens students' self-efficacy, time management, and study strategies (Çakıroğlu & Öztürk, 2017; Lai & Hwang, 2016). The incorporation of SRL into FL has yielded positive results across diverse fields including mathematics education (Lai & Hwang, 2016; Sun et al., 2018), history education (van Alten et al., 2020b), medical education (Zheng & Zhang, 2020), music teacher education (Montgomery et al., 2019), education for English as a foreign language (Öztürk & Çakıroğlu, 2021), programming language education (Çakıroğlu & Öztürk, 2017), and science education (Sletten, 2017).

Within this assortment, science education holds an important position in encouraging students' SRL (Winne, 2022) and designing flipped instruction (González-Gómez et al., 2016; Jdaitawi, 2020). Prior studies have revealed that self-regulated science instruction effectively fosters achievement and promotes self-regulation

across primary, secondary, and higher education levels (Devolder et al., 2012; Fang et al., 2022; Maison & Syamsurizal, 2019; Schraw et al., 2006; Stevenson et al., 2017). Concurrently, FL has gained prominence in science education due to its potential to enhance academic outcomes (Bergmann & Sams, 2012; Kazeminia et al., 2022; Nja et al., 2022). By inverting traditional instructional methods and assigning lectures as homework while dedicating class time to problem-solving, FL fosters a profound understanding of scientific concepts (Abeysekera & Dawson, 2015; Gao & Hew, 2022). This learner-centered approach encourages active participation and collaboration (Chen et al., 2022; Tucker, 2012), leading to improved retention and critical thinking skills (Chen et al., 2022; Mazur, 2009). Despite these positive findings, Chen et al. (2022) have underscored the limited availability of research involving middle school students and countries outside of the USA. To bridge this gap and better understand FL's global applicability, further investigation is necessitated, especially within diverse educational contexts and across varied age groups.

There is a dearth of studies examining the SRFL in science education, which integrates self-regulated science learning into FL, thereby fostering students' academic cognition, motivation, and behaviors (Sletten, 2017). To bridge this gap, the current study seeks to test the self-regulated flipped learning approach (SRFLA) proposed by Lai and Hwang (2016) by implementing a middle school science topic in Turkey. The study aims to assess middle school students' learning performance, attitudes, SRL levels, and science learning motivation. The following research questions were explored:

- Do students who engage in the SRFLA achieve significantly more success than those who learn with the standard FL approach?
- Do students who engage in the SRFLA demonstrate significantly more positive attitudes towards science learning than those who learn with the standard FL approach?
- Do students who engage in the SRFLA display higher levels of self-regulation than those who learn with the standard FL approach?
- Do students who engage in the SRFLA exhibit a higher degree of motivation for science learning than those who learn with the standard FL approach?

2. Literature review

2.1. Flipped learning

FL encompasses a broad spectrum of instructional techniques that are applied distinctively by different educators and researchers (Leo & Puzio, 2016). Bergmann and Sams (2012) explain that in a flipped classroom, students engage with instructional videos or other learning materials at home prior to attending class. Class time is consequently used for problem-solving, collaborative activities, and projects, allowing teachers to provide personalized support and guidance tailored to each student's individual needs, thereby fostering active learning. Bishop and Verleger (2013) further characterize the flipped classroom as an innovative instructional strategy that melds asynchronous video lectures and practice exercises assigned as homework with active, group-oriented problem-solving activities conducted within the classroom. They also assert that this methodology uniquely amalgamates seemingly incompatible learning theories, incorporating both active, problem-based learning based on constructivist principles and instructional lectures derived from behaviorist direct instruction methods.

FL aspires to enhance the classroom environment's efficacy by engaging students in quality interactions with both teachers and peers, facilitating profound learning (Jong, 2017; Jong, 2019; O'Flaherty & Phillips 2015). Within the FL paradigm, course content is made accessible for students' perusal, followed by active guidance from teachers in problem-solving, leading discussions, and enriching students' learning experiences (Hao & Lee, 2016). Classroom learning may comprise a diverse array of educational activities such as teaching laboratory courses (Elkhatat & Al-Muhtaseb, 2021), reflection (Talley & Scherer, 2013), game-based learning (Hwang, & Chang, 2023; Parra-González et al., 2020; Tao et al., 2016), demonstrations (Gupta, 2020), discussions (Bognar et al., 2019), and small group projects (Ramnanan & Pound, 2017). Beyond the classroom, the learning process extends to various educational activities such as using videos, readings, quizzes, discussions, PowerPoint presentations, and online modules (Akçayır & Akçayır, 2018).

FL offers several potential benefits to students (Giannakos et al., 2014), teachers (Al-Naabi et al., 2022), and researchers (Karabulut-Ilgu et al., 2018). According to Akçayır and Akçayır (2018), these advantages can be categorized into six domains: learner outcomes, pedagogical contributions, dispositions, interaction, time efficiency, and miscellaneous benefits. Learner outcomes include improvements in student learning processes such as satisfaction, performance, and engagement levels. Pedagogical contributions provided by FL include the enhancement of flexibility and individualized learning in the educational process. Furthermore, FL enables both

teachers and students to use their time efficiently, fosters positive attitudes towards the learning process, and improves the interaction between students and teachers. However, alongside its benefits, FL also presents certain challenges. Akçayır and Akçayır (2018) classify these challenges into five categories: pedagogical, students' and teachers' perspectives, technical & technological, and other miscellaneous issues. Among these, the most common challenge lies in out-of-class activities, specifically the limitations in student preparation during the teaching process. Additionally, time consumption emerges as a frequent concern expressed by both students and teachers. A considerable number of studies report that teachers often encounter technical issues during FL, such as video quality. Another challenge is that students sometimes struggle with transitioning between in-class and out-of-class environments (Wanner & Palmer, 2015).

FL has garnered significant interest within the realm of science education due to its unique pedagogical approach (Alrashed & Bin, 2021). An examination of research concerning FL within science education indicates that students' learning outcomes, perceptions, and attitudes represent primary foci for researchers (Chen et al., 2019). Considering that FL constitutes a relatively novel instructional methodology, comprehending its influence on students' academic performance and perspectives is pivotal for its successful incorporation. Various studies have confirmed the positive impact of FL on multiple aspects of science education, including students' academic performance, collaboration, communication, and higher-order cognitive skills (Canelas et al., 2017; Olakanmi, 2017). Additionally, FL appears to enhance students' perceptions of learning and motivation levels (Aşıksoy & Özdamlı, 2016; Sezer, 2017).

One facet of FL that has attracted considerable attention is students' learning behavior, particularly during the pre-class stage (Chen et al., 2019). Despite established evidence confirming the effectiveness of FL, the concerns of researchers and educators persist regarding students' learning status during this crucial phase. Studies exploring correlations or causality have demonstrated that students' engagement significantly influences their academic performance (Gross et al., 2015), indicating that learning behaviors in the pre-class stage substantially impact students' overall performance. A recent literature review conducted by Turan (2023) explored whether FL enhances student learning in science education and analyzed 64 studies. The results, aligned with the findings frequently emphasized in prior research, revealed that FL improves students' academic performance in science, fosters positive attitudes, perceptions, and views towards science, reduces withdrawal rates, boosts motivation, enhances student satisfaction and engagement, facilitates comprehensive understanding, and positively influences students' emotions. Nonetheless, while FL produces successful outcomes, social interactions between students and teachers remain insufficient, necessitating SRL that enables students to orchestrate their learning processes (Broadbent & Poon, 2015).

The interplay between FL and SRL is of considerable importance, as it significantly influences students' success in a FL environment (Shyr & Chen, 2018). SRL refers to students' capacity to orchestrate their learning processes, encompassing planning, monitoring, and reflecting on their learning activities (Zimmerman, 2002). Self-regulating students can set goals, select appropriate strategies, monitor their progress, and evaluate their learning outcomes (Pintrich, 2004). Given that FL environments necessitate students' active participation in their learning, SRL emerges as a crucial determinant of success in FL (O'Flaherty & Phillips, 2015). In a FL environment, SRL is indispensable for students to profit from both in-class and out-of-class learning activities. For instance, students must effectively plan and manage their time to engage with pre-class materials and partake in in-class activities (Akçayır & Akçayır, 2018). Moreover, self-regulation assists students in monitoring their learning progress and adjusting their strategies as necessary (Zimmerman, 2002), which is particularly important in a FL environment where students exercise greater autonomy over their learning (Yoon et al., 2020; Zainuddin & Perera, 2019).

Numerous studies have probed the relationship between FL and components of SRL. For instance, Silva et al. (2018) found that students in a FL environment exhibited enhanced levels of self-regulation, particularly in terms of planning and monitoring. Similarly, Çakıroğlu and Öztürk (2017) investigated the development of self-regulation in a flipped classroom setting employing problem-based learning activities and found that during face-to-face learning sessions designed with problem-based activities using the flipped classroom model, students displayed high levels of goal setting, planning, task strategies, and help-seeking skills. In at-home sessions, students exhibited high levels of environment structuring, goal setting, and planning skills. The study conducted by Sletten (2017) found that students' perceptions of the flipped model positively predicted their use of several types of SRL strategies. It was also observed that the success of flipped classrooms lies in active learning sessions facilitated by constructivist teaching methodologies. Although video lectures are an integral component of flipped classrooms, students may need to practice SRL skills to become more self-directed learners and to effectively engage with the video content.

2.2. Self-regulated learning

SRL, as defined by Pintrich (2000, p. 453), is “an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment.” Zimmerman and Schunk (2011, p.1) offer a similar definition, suggesting SRL as “the process whereby learners personally activate and sustain cognitions, affects, and behaviors that are systematically oriented toward the attainment of learning goals.” Zimmerman (2002) further divides SRL into three distinct phases: the forethought phase, the performance phase, and the self-reflection phase. During the forethought phase, students are tasked with analyzing learning assignments and determining specific goals and strategies to achieve these objectives (Lai & Hwang, 2016). The performance phase involves students in actively monitoring and controlling their learning progress (Moos & Bonde, 2016; Zimmerman & Moylan, 2009). Finally, the self-reflection phase necessitates students’ evaluation of their learning efficiency and the effectiveness of the applied learning strategies (Lai & Hwang, 2016).

SRL significantly contributes to academic success (Cho & Shen, 2013; Littlejohn et al., 2016) and motivation (Michalsky & Schechter, 2013), as it enables students to manage their learning plans, fuel their learning motivation, and adjust learning strategies as needed (Butler & Winne, 1995; Heikkilä & Lonkka, 2006; Lai & Hwang, 2016). In the SRL process, cognitive, metacognitive, affective, and motivational elements play a pivotal role in propelling students’ learning (Boekaerts, 1997). FL, renowned for its potential to foster SRL among students, can be synergistically integrated with SRL (Sun et al., 2018; Kim et al., 2021; Yoon et al., 2021; Zheng & Zhang, 2020). By encouraging students to actively participate in the learning process, FL can enhance the development of SRL skills, which are indispensable for both academic success and lifelong learning (Boyer et al., 2014; Zimmerman, 2002). FL empowers students to assume responsibility for their own learning (Bergmann & Sams, 2012). In this environment, students are expected to review course materials and engage in learning activities outside of class, preparing them for active in-class participation (Abeysekera & Dawson, 2015). This shift in responsibility promotes the application of SRL components, such as planning, goal setting, and the selection of appropriate learning strategies (Pintrich, 2000; Zimmerman, 2000). Furthermore, the FL environment provides opportunities for students to exercise SRL skills through various activities and assessments. Self-assessment tools, such as quizzes or reflection prompts, enable students to monitor their understanding and adjust their learning strategies accordingly (Fulton, 2012; Moos & Bonde, 2016). Through this monitoring process, students can develop a heightened metacognitive awareness, a vital aspect of SRL (Zimmerman, 2002). In addition, FL encourages reflection on learning experiences (Petichakis, 2022). By applying learned concepts through in-class activities, students can deepen their understanding and reflect on their learning journey (Howell, 2021; Lin et al., 2021). Such reflections help students to evaluate the effectiveness of their learning strategies, subsequently improving their SRL skills (Abeysekera & Dawson, 2015; Chen et al., 2019). Lastly, FL facilitates student-teacher interactions and peer collaborations, which can support the development of SRL (Bhagat et al. 2016; Lo & Hew, 2017). In an FL classroom, teachers can provide individualized guidance and feedback, enabling students to refine their learning strategies and evolve into more self-regulated learners (Moffett, 2015; Sletten, 2017; Wanner & Palmer, 2015). Group activities within an FL environment, such as projects or discussions, can promote social regulation of learning, a crucial aspect of SRL (Çakıroğlu, & Öztürk, 2017; Hadwin et al., 2011; Yoon et al., 2021). Given these significant advantages, the integration of FL and SRL has been the subject of increasing interest among researchers globally.

In a study spearheaded by Lai and Hwang (2016), a SRFLA was deployed to elevate the mathematical achievements of fourth-grade students in an elementary school in Taiwan. Findings revealed that students engaged in SRL demonstrated superior learning achievements and higher self-efficacy compared to those exposed to traditional FL design. Moreover, the approach was instrumental in enhancing students’ abilities to plan and optimally utilize study time. Parallel outcomes were noted in a study by Yoon et al. (2021) conducted at a United States university, where FL was leveraged as a learning environment. The findings indicated that undergraduate students within the SRL group exhibited advanced SRL skills, improved learning performance, heightened behavioral engagement prior to class, and increased cognitive engagement during in-class sessions. These students also demonstrated increased emotional engagement before and after classes, compared to their counterparts in the non-SRL group. A separate study by Sun et al. (2018) examined the role of SRL in shaping students’ success in mathematics within an FL context in the United States. The research affirmed that students’ self-efficacy in a math course and their utilization of help-seeking strategies were positively correlated with their academic achievement. van Alten et al. (2020a) embarked on an empirical study scrutinizing the influence of SRL support on students’ self-reported activities, online engagement, learning outcomes, and satisfaction in an eight-week flipped history course. Although the study concluded that SRL contributes significantly to students’ academic success, it did not necessarily enhance their satisfaction levels. In light of these findings, the present study hypothesizes that middle school students possessing higher levels of self-regulation are likely to be more

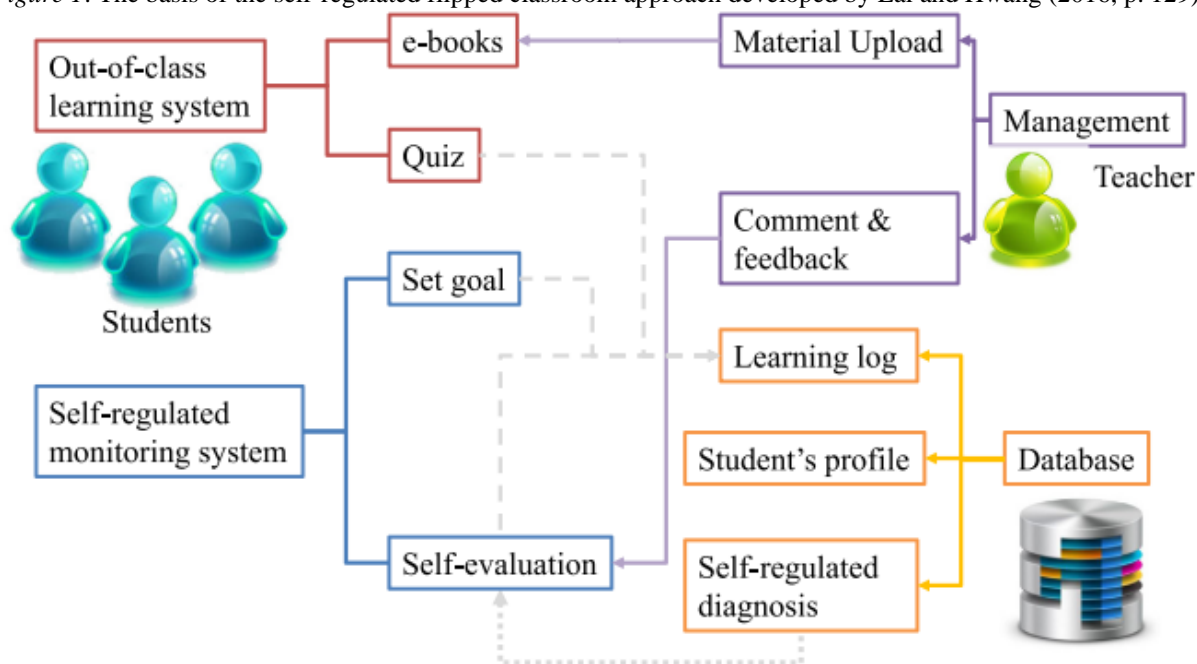
successful in a science course within an FL environment than those with lower levels of self-regulation. Consequently, the research aimed to assess the impact of the SRFLA on middle school students' academic achievement, attitudes, levels of SRL, and motivation within the sphere of science education.

2.3. Self-regulated flipped classroom approach

The Self-Regulated Flipped Classroom Approach (SRFLA), developed by Lai and Hwang (2016), was adapted for use in this study to support the learning activities within a flipped classroom context. The SRFLA comprises an out-of-class learning system, a self-regulated monitoring system, a teacher management system, and a database. The out-of-class learning system is equipped to provide students with e-books and quizzes, designed to be completed prior to in-class activities. In tandem, the self-regulated monitoring system is built to enable students to establish their learning objectives and assess their own performance. The teacher management system, on the other hand, allows educators to upload e-books and offer feedback to students. The database, a critical component of the SRFLA, is responsible for recording students' learning logs, maintaining profiles, and generating diagnostics based on the educator's criteria and the students' learning logs.

The learning process under the SRFLA commences with an introduction to the syllabus and a detailed explanation of the self-regulation and flipped classroom learning modes. Students then proceed to set learning goals based on their past experiences and utilize the out-of-class learning system to study e-books and attempt quizzes. Teachers, in their role, monitor students' learning logs and overall performance. They conduct discussions and offer supplementary knowledge during in-class activities. Post-lesson, students engage in self-evaluation, and the database, in turn, provides diagnostic insights based on their performance to make necessary adjustments to self-regulation. The goal-setting interface necessitates students to set specific goals related to their desired scores, time allocation, learning location, and strategies. After these goals are set, students access the e-books and complete the quizzes before in-class activities. The system logs the time spent and records quiz responses, facilitating both students and teachers to monitor performance. In-class activities are centered around discussing out-of-class learnings and providing extended instruction. Upon the completion of each unit, students perform self-evaluations, submitting their results, and reviewing teachers' feedback. The teachers' comments are crafted based on students' goals, actual scores, system recordings, and the criteria set by the teachers. The self-regulated diagnostic aspect encompasses performance management and self-evaluation. The system computes an individualized learning diagnosis for each student, delivering instantaneous personal diagnoses, which in turn enable students to self-reflect and establish goal-setting for the subsequent learning unit. The structure of the approach is depicted in Figure 1.

Figure 1. The basis of the self-regulated flipped classroom approach developed by Lai and Hwang (2016, p. 129)



3. Method

3.1. Research design

This study adopted a quasi-experimental design, incorporating a pre-test/post-test control group framework, in which participants were not randomly assigned to respective groups (Fraenkel et al., 2012). The design was implemented to compare the level of conceptual understanding among middle school students taught via a self-regulated flipped classroom approach, with those taught through the standard flipped classroom method.

3.2. Participants

Participants in this study were eighth-grade students from a middle school located in a mid-sized city in the central Anatolian region of Turkey. Characteristic of state schools, the majority of the students were from middle-income families. Notwithstanding, they encountered no technical impediments, such as access to a mobile device or an internet connection. As detailed in Table 1, the study comprised a total of 59 students (32 males, 27 females), aged between 13 and 14 years ($M = 13.78$, $SD = 0.34$). These students were allocated into either the control group ($N = 30$) or the experimental group ($N = 29$). The same teacher was entrusted with delivering the science instruction across both groups.

Table 1. Characteristics of participants in terms of gender and group

Gender	Experimental group	Control group
Female	14	13
Male	15	17
Total	29	30

3.3. Experimental procedure

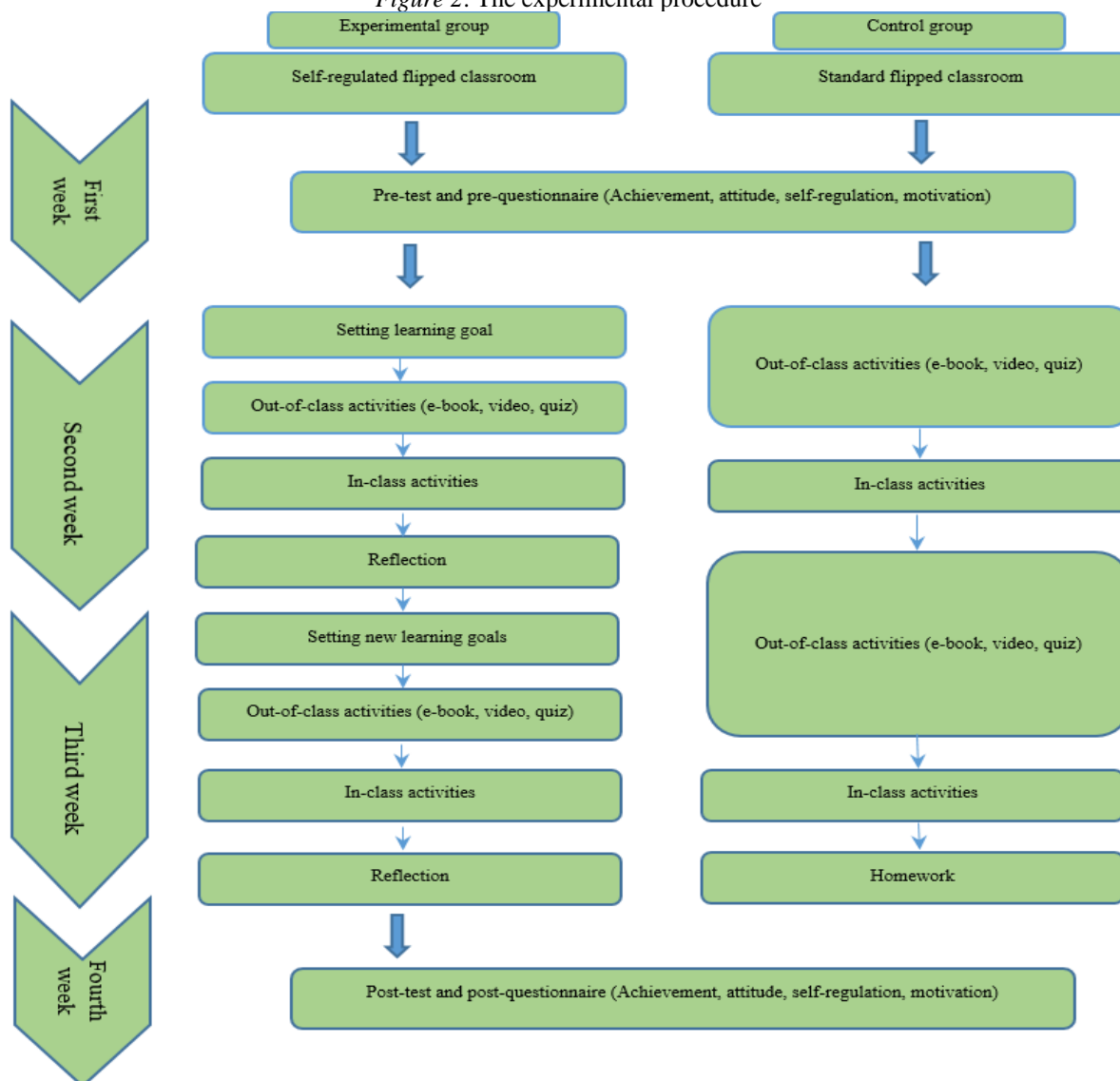
The study's experimental procedure was conducted within the framework of the "DNA and Genetic Code" unit for 8th-grade students during the 2022-2023 academic year. Before the study's commencement, comprehensive informed consent forms, outlining details of the students' participation, the voluntary nature of their involvement, the study's benefits and risks, any potential discomforts, confidentiality measures, and contact information were distributed to all participating students and their families. The procedure strictly complied with the science curriculum developed by the Turkish Ministry of National Education (2018). The students in the control group received instruction via the standard FL approach, while those in the experimental group participated in the SRFLA. The creation of technology tools spanned a period of seven weeks, succeeded by a four-week experimental process.

During the seven-week period, a comprehensive set of FL resources, including an e-book (see Figure 3), instructional videos (see Figure 4), and online quizzes (see Figure 5), were developed to cover the science topic at hand. The initial week involved rigorous research into the topics, leading to the formulation of an outline for the e-book and instructional videos. This included chapter titles, subheadings, learning objectives, and key concepts. From the second week through to the fourth week, the creation of content for the e-book chapters, instructional video scripts, and online quiz materials took place concurrently. In the fifth week, a thorough review and editing process was conducted for the e-book, instructional videos, and quizzes, to ensure clarity, coherence, and accuracy, integrating revisions based on feedback from peers and subject matter experts. The sixth week was devoted to designing the e-book layout, incorporating text formatting, illustrations, and diagrams, and adapting it for compatibility across various devices and platforms. Concurrently, the instructional videos underwent recording, editing, and finalization processes, with the integration of visuals, animations, and voiceovers to enrich the learning experience. The online quizzes were fine-tuned and tested for functionality, while all materials were compiled into a user-friendly platform for easy access and navigation. The seventh and final week entailed a thorough final review of the e-book, instructional videos, and online quizzes to ensure their accuracy, readability, and engagement potential. Once approved, these FL resources were hosted on designated learning platforms and disseminated to the intended audience.

The study's experimental procedure was carried out over a four-week period. To uphold the validity and reliability of the study, a series of experimental controls were applied. These included maintaining consistency in learning materials, the teacher's role, monitoring of out-of-class activities, pre-test and post-test measurements, the study's duration and sequence, and the employment of a quasi-experimental pre-test/post-test control group

design. With the integration of these controls, the study strived to furnish a robust comparison of the SRFLA and the standard FL approach, thereby enriching the expanding corpus of research on FL in science education. During the first week of the experiment, the teacher elucidated the learning outcomes and expectations for the unit to the students, ensuring they understood the knowledge they were to acquire and the skills they were to develop throughout the unit. Each activity during this week was designed to span approximately four hours. The students were equipped with an e-book and instructional videos covering the subjects to be tackled during the unit. They also undertook the achievement, attitude, self-regulation, and motivation questionnaires as a pre-test. This design's rationale was to establish a foundational understanding of the students' existing knowledge and skills prior to engaging in FL and self-regulatory activities.

Figure 2. The experimental procedure



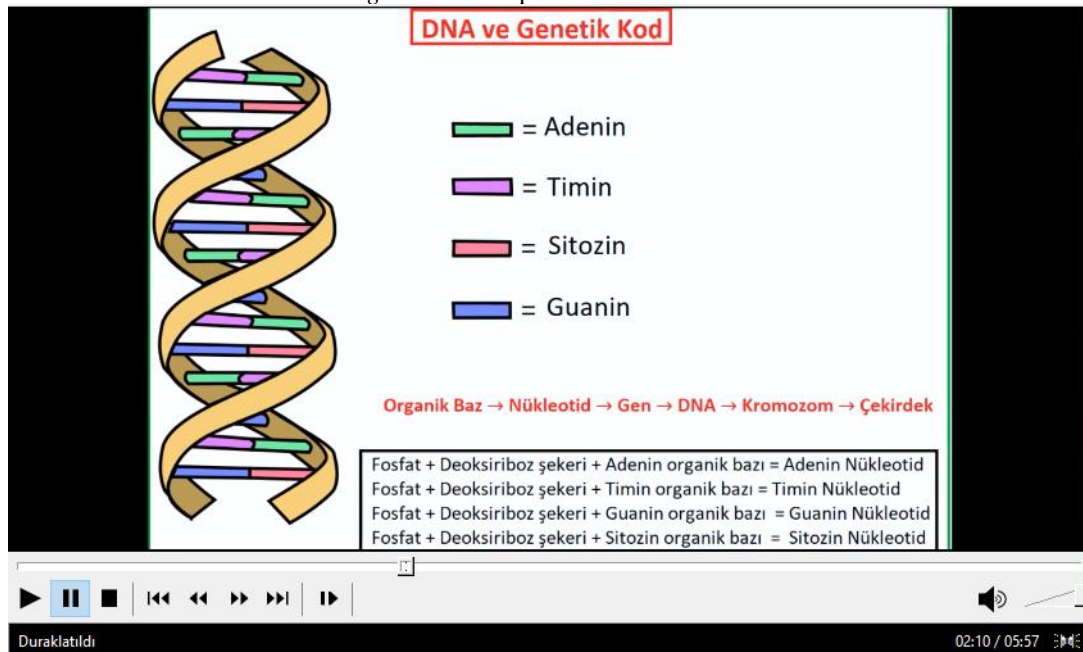
In the second and third weeks, the focus shifted towards the science topic, which included the structure of DNA, DNA replication, nucleotides, genes, and chromosomes. Each out-of-class activity was designed without a rigid time constraint, enabling students to learn at their own pace from home. This duration flexibility was intended to accommodate diverse learning styles and preferences, thereby fostering a more efficient learning experience for all students. Both the experimental and control groups partook in out-of-class activities, involving studying the e-book, viewing the instructional videos, and completing online quizzes. During this phase, the experimental group was directed to set learning goals and self-evaluate their progress, thereby encouraging self-regulation within the learning process. The teacher monitored the students' out-of-class activities to guarantee equal exposure to the learning materials and activities across both groups. The in-class activities during this week, designed to last approximately four hours, encompassed a brief review of the topics covered, followed by small-group problem-solving tasks constructed to stimulate critical thinking, collaboration, and application of the concepts learned. Consistent feedback was provided to both groups by the teacher, and the experimental group was encouraged to

appraise and reflect on their learning, setting new goals for the subsequent week based on their reflections. The rationale behind this design was to blend the essential elements of FL, such as engaging students with content outside the classroom and promoting active learning, with self-regulated learning strategies like goal-setting and self-assessment.

Figure 3. The user interface of the e-book



Figure 4. A sample instructional video



In the concluding week of the study, all students were required to complete achievement, attitude, self-regulation, and motivation questionnaires as post-tests. The purpose of this assessment was to identify any shifts in these domains as a consequence of the educational intervention. For consistency, each activity was

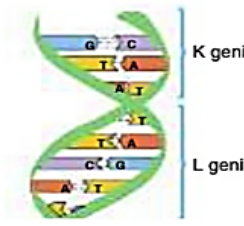
meticulously scheduled to last approximately four hours. This exhaustive evaluation facilitated a more profound understanding of the SRFLA's impact on middle school students' academic achievement, attitudes, self-regulation, and motivation. Figure 2 outlines the four-week procedural framework used in conducting the study.

Figure 5. A sample question in the online quiz

DNA molekülü üzerinde K ve L genleri gösterilmiştir.
K geni ile ilgili olarak bilinen bazı bilgiler aşağıda verilmiştir.

1. bilgi: Nükleotid diziliş sırası G-C, T-A, A-T şeklindedir.
2. bilgi: Yapısında 4 çeşit nükleotid vardır.

Bu bilgilerin hangileri L geni için farklılık gösterir?



Her iki bilgi de farklılık gösterir.

Sadece 1. bilgi farklılık gösterir.

Her iki bilgi de farklılık göstermez

Sadece 2. bilgi farklılık gösterir.

3.4. Measures

Several scales were used for data collection in this study, including the achievement test, attitude scale, self-regulated learning (SRL) scale, and motivation scale.

3.4.1. Achievement test

The achievement test was designed to assess students' understanding of the "DNA and Genetic Code" unit. The unit aimed for students to acquire knowledge and skills related to DNA and genetic code, understand concepts like inheritance, mutation, modification, adaptation, selection, variation, genetic engineering, and biotechnology applications, and to discuss their positive and negative effects (Turkish Ministry of National Education, 2018). An achievement test was developed to evaluate the attainment of the unit's intended outcomes and was administered both before and after the experimental period. The test contained 25 multiple-choice items, derived from previous exams administered by the Turkish Ministry of National Education, with a maximum attainable score of 100. All students were administered the same achievement test. The test's reliability coefficient was found to be 0.82.

3.4.2. Attitude scale

The attitude scale, crafted by Oguz (2002), is unidimensional and gauges overall attitudes toward science. It comprises 20 items, rated on a 5-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree." An exemplar item from the scale is "I like my science course." The scale has demonstrated a high level of internal consistency, with a Cronbach's alpha coefficient of 0.87. This unidimensional feature of the scale facilitates a focused analysis of students' overall attitudes towards science in the context of FL.

3.4.3. Self-regulated learning scale

The SRL scale, developed by Barnard et al. (2009), incorporates 24 items with a 5-point Likert-type scale ranging from strongly disagree (1) to strongly agree (5). The scale's reliability coefficient was calculated to be

0.89). The scale's original form consists of six sub-dimensions: "Goal Setting" ($\alpha = 0.92$), "Environment Structuring" ($\alpha = 0.88$), "Task Strategies" ($\alpha = 0.90$), "Time Management" ($\alpha = 0.85$), "Help Seeking" ($\alpha = 0.93$), and "Self-Evaluation" ($\alpha = 0.91$).

3.4.4. Motivated strategies for learning questionnaire

The Motivated Strategies for Learning Questionnaire (MSLQ), developed by Pintrich et al. (1991), assesses students' motivational orientations and their employment of various learning strategies. The MSLQ, with proven reliability and validity, has been extensively utilized for measuring motivational and SRL variables (Duncan & McKeachie, 2005). For this study, the MSLQ's "Intrinsic Goal Orientation" ($\alpha = 0.72$), "Extrinsic Goal Orientation" ($\alpha = 0.75$), "Task Value" ($\alpha = 0.88$), and "Self-efficacy for Learning and Performance" ($\alpha = 0.83$) constructs were employed, given their comprehensive coverage of SRL facets (van Alten et al., 2020a). Each construct contains four items rated on a 5-point scale, ranging from 1 (not at all true of me) to 5 (very true of me).

3.5. Data analysis

The data in this study were analyzed using the Statistical Package for the Social Sciences (SPSS), Version 22. Throughout the analytical process, Cronbach's alpha values were determined for each scale to assess reliability. Descriptive statistics were executed with the use of central tendency measures, such as the mean and standard deviation. In order to evaluate the differences between the control and experimental groups prior to the intervention, a one-way multivariate analysis of variance (MANOVA) was implemented. A two-way Analysis of Variance (ANOVA) was conducted to identify whether significant differences existed between the two teaching methods, namely the SRFLA and the traditional FL approach. Additionally, another two-way ANOVA was undertaken to assess differences between pre-test/questionnaire and post-test/questionnaire scores concerning the study's primary variables, which included achievement, attitudes toward science, self-regulation learning skills, and motivation. Lastly, the impact of the SRFLA on the sub-dimensions of "Self-Regulatory Learning Skills" and "Motivation" was examined using an independent sample t-test.

4. Results

4.1. Examination of pre-test score differences

In alignment with the foundational approaches of the quasi-experimental design, an initial analysis was carried out to determine whether a significant difference existed between the control group and the experimental group in the pre-tests and pre-questionnaires. A one-way MANOVA was conducted to investigate the potential difference between the control group and the experimental group in relation to pre-tests and pre-questionnaires, focusing on achievement, attitudes toward science, self-regulated learning, and motivation. The results indicated no significant difference between the conditions in pre-scale scores ($F(6, 108) = 0.74$, $p = .619$; Wilk's $\Lambda = 0.961$).

4.2. Effects of the self-regulated flipped learning

This study examined the effect of SRFLA on science achievement, attitude toward science, SRL, and motivation.

4.2.1. Biology achievement

The two-way ANOVA results revealed a statistically significant difference with respect to educational interventions ($F = 9.018$, $p < .01$) and students' biology achievement ($F = 15.316$, $p < .01$). Moreover, no significant interaction was found between these variables ($F = 3.19$, $p > .05$). The mean values and standard deviations of the post-test achievement scores were 84 and 5.79 for the experimental group, and 68 and 6.21 for the control group. These findings suggest that the SRFLA can enhance students' achievements more effectively than the traditional FL approach. Furthermore, the results demonstrated that students' biology achievement in the post-test scores was significantly higher than their pre-test scores, indicating that the SRFLA could improve

students' biology achievement. Descriptive statistics and ANOVA results for students' biology achievements are presented in Tables 2 and 3.

Table 2. Descriptive statistics of the students' biology achievements of the two study groups

Achievement test	Experimental group			Control group		
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>
Pre-test	29	28	8.87	30	32	8.51
Post test	29	84	5.79	30	68	6.21

Table 3. The two-way ANOVA results of the achievement test and study groups in terms of post-test scores

Variables	<i>df</i>	<i>F</i>	<i>p</i>
Educational treatments	1	9.018	.005
Achievement	1	15.316	.001
Study groups \times Achievement	1	3.19	.12
Error	57		

4.2.2. Attitude toward science

The mean values and standard deviations of the post-questionnaire scores were 4.67 and 1.03 for the experimental group, and 4.19 and 1.12 for the control group. The experimental results revealed a significant effect between the experimental group and the control group ($F = 12.33$, $p = .008$). This indicates that students who learned using the SRFLA exhibited significantly higher attitudes toward science compared to those who learned through the traditional FL approach. Furthermore, the ANOVA results demonstrated a significant difference between pre-questionnaire scores and post-questionnaire scores ($F = 11.14$, $p = .004$), suggesting that the SRFLA effectively improved students' attitudes toward science. Nonetheless, no interaction was detected between the variables ($F = 13.48$, $p = .19$). Tables 4 and 5 present the descriptive statistics and two-way ANOVA results concerning students' attitudes toward science.

Table 4. Descriptive statistics of the students' attitudes toward science of the two study groups

Attitude toward science	Experimental group			Control group		
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>
Pre-test	29	3.52	1.18	30	3.47	1.22
Post test	29	4.67	1.03	30	4.19	1.12

Table 5. The two-way ANOVA results of the attitude scale

Variables	<i>df</i>	<i>F</i>	<i>p</i>
Study groups	1	12.33	.008
Attitude	1	11.14	.004
Study groups \times Attitude	1	13.48	.19
Error	57		

4.2.3. Self-regulatory learning skills

The mean values and standard deviations of the self-regulatory learning skills for post-questionnaire scores were 4.01 and 1.30 for the control group, and 4.39 and 1.11 for the experimental group. The findings revealed a significant effect for teaching methods ($F = 5.78$, $p = .007$) and self-regulatory learning skills ($F = 7.89$, $p = .003$). These results suggest that learning through the SRFLA can enhance students' self-regulatory learning skills more effectively than the traditional FL approach. Additionally, the analysis indicated that students' self-regulatory learning skills significantly improved following the implementation of the teaching method. However, no significant interaction was observed ($F = 9.12$, $p = .12$). Tables 6 and 7 display the results of the descriptive statistics and the two-way ANOVA concerning students' self-regulatory learning skills.

To gain a deeper understanding of the students' self-regulatory learning skills with regards to sub-dimensions including environment structuring, goal setting, help seeking, self-evaluation, task strategies, and time management, an independent *t*-test was employed as indicated in Table 8. The results disclosed no significant disparity between the self-regulatory learning skills ratings for each dimension in the pre-questionnaire for the control and experimental groups ($t_{range} = 0.89-2.42$, $p > .05$), signifying that students in both groups possessed

similar levels of self-regulatory learning skills before embarking on their flipped classroom. This study went a step further by juxtaposing the six dimensions of self-regulatory learning skills in the post-questionnaire.

Table 6. Descriptive statistics of the students' self-regulatory learning skills

Self-regulatory learning skills	Experimental group			Control group		
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>
Pre-test	29	3.42	1.27	30	4.29	1.47
Post test	29	4.39	1.11	30	4.01	1.30

Table 7. The two-way ANOVA results of the self-regulatory learning skills

Variables	<i>df</i>	<i>F</i>	<i>p</i>
Study groups	1	5.78	.007
Self-regulatory learning skills	1	7.89	.003
Study groups \times Self-regulatory learning skills	1	9.12	.12
Error	57		

The statistical analysis revealed that students in the experimental group exhibited a significantly heightened awareness of goal setting ($M = 4.20$, $SD = 0.55$) in comparison to the control group ($M = 3.65$, $SD = 0.50$), $t = 3.60$, $p = .001$. Likewise, the experimental group demonstrated a markedly enhanced understanding of task strategies ($M = 4.15$, $SD = 0.60$) as opposed to the control group ($M = 3.40$, $SD = 0.58$), $t = 4.25$, $p = .001$. With regard to time management awareness, the experimental group ($M = 4.05$, $SD = 0.62$) significantly outperformed the control group ($M = 3.45$, $SD = 0.57$), $t = 3.45$, $p = .002$. Furthermore, the experimental group ($M = 4.30$, $SD = 0.54$) achieved notably higher scores in help-seeking awareness relative to the control group ($M = 3.75$, $SD = 0.51$), $t = 3.85$, $p = .001$. Lastly, in the dimension of self-evaluation, the experimental group ($M = 4.10$, $SD = 0.59$) significantly exceeded the control group ($M = 3.55$, $SD = 0.56$), $t = 3.30$, $p = .003$.

Table 8. Comparison of dimensions of self-regulatory learning skills between experimental and control groups

Dimension	Group	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Goal Setting	Experimental	4.20	0.55	3.60	.001
	Control	3.65	0.50		
Task Strategies	Experimental	4.15	0.60	4.25	.001
	Control	3.40	0.58		
Time Management	Experimental	4.05	0.62	3.45	.002
	Control	3.45	0.57		
Help-Seeking	Experimental	4.30	0.54	3.85	.001
	Control	3.75	0.51		
Self-Evaluation	Experimental	4.10	0.59	3.30	.003
	Control	3.55	0.56		

4.2.4. Motivation

Regarding motivation, as illustrated in Tables 9 and 10, the mean values and standard deviation were 4.59 and 1.42 for the experimental group, and 4.11 and 1.54 for the control group. The two-way ANOVA result revealed a significant difference in relation to the teaching method ($F = 10.89$, $p = .009$). Additionally, a significant difference was found between pre and post-questionnaires concerning students' motivations ($F = 13.45$, $p = .005$). These findings suggest that students who engaged in learning with the SRFLA exhibited higher motivation than those who participated in the traditional FL approach. Moreover, the results indicate that the SRFLA was more effective in enhancing post-questionnaire scores compared to pre-questionnaire scores. The study also determined that there was no significant interaction between the variables ($F = 9.77$, $p = .09$).

Table 9. Descriptive statistics of the students' motivations

Motivation	Experimental group			Control group		
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>
Pre-test	29	3.11	1.78	30	3.01	1.69
Post test	29	4.59	1.42	30	4.11	1.54

Table 10. The two-way ANOVA results of the motivations

Variables	<i>df</i>	<i>F</i>	<i>p</i>
Study groups	1	10.89	.009
Motivation	1	13.45	.005
Study groups × Motivation	1	9.77	.09
Error	57		

The *t*-test results comparing the sub-dimensions of motivation including “intrinsic goal orientation,” “extrinsic goal orientation,” “task value,” and “self-efficacy for learning and performance” between the experimental and control groups are presented Table 11. The analysis was conducted using an alpha level of 0.01 to determine the significance of the differences between the two groups. Firstly, the analysis revealed a significant difference in intrinsic goal orientation between the experimental group ($M = 4.25$, $SD = 0.65$) and the control group ($M = 3.70$, $SD = 0.62$, $t = 3.15$, $p = .003$). This result suggests that the students in the experimental group had a higher level of intrinsic goal orientation compared to their counterparts in the control group. Secondly, the extrinsic goal orientation was found to be significantly different between the experimental group ($M = 4.10$, $SD = 0.58$) and the control group ($M = 3.55$, $SD = 0.60$, $t = 2.90$, $p = .006$). The experimental group displayed a stronger extrinsic goal orientation as opposed to the control group. In addition, the task value was significantly higher in the experimental group ($M = 4.35$, $SD = 0.63$) compared to the control group ($M = 3.45$, $SD = 0.61$, $t = 4.05$, $p = .001$). This finding indicates that students in the experimental group placed a greater value on the tasks than students in the control group. Lastly, a significant difference was observed in the self-efficacy for learning and performance between the experimental group ($M = 4.20$, $SD = 0.67$) and the control group ($M = 3.50$, $SD = 0.64$, $t = 3.80$, $p = .001$). Students in the experimental group demonstrated a higher level of self-efficacy for learning and performance as compared to their peers in the control group.

Table 11. Comparison of motivation sub-dimensions between experimental and control groups

Sub-Dimensions	Group	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Intrinsic Goal Orientation	Experimental	4.25	0.65	3.15	.003
	Control	3.70	0.62		
Extrinsic Goal Orientation	Experimental	4.10	0.58	2.90	.006
	Control	3.55	0.60		
Task Value	Experimental	4.35	0.63	4.05	.001
	Control	3.45	0.61		
Self-Efficacy for Learning & Performance	Experimental	4.20	0.67	3.80	.001
	Control	3.50	0.64		

5. Discussion and implications

The reviews by Chen et al. (2022) and Turan (2023) have indicated an increasing number of studies on the FL approach in science education in recent years. Prior research underscores the efficacy of the FL approach in enhancing students’ science achievements, attitudes toward science, motivation, satisfaction, comprehension, and emotional engagement. However, as technological advancements and the evolving needs of students continue to shape science education, it becomes increasingly important for students to take charge of their learning processes (Ateş & Garzón, 2022; Ateş & Garzón, 2023; Zydney & Warner 2016). In light of this information, SRL makes significant contributions to fulfilling students’ learning needs (van Alten et al., 2020a; Jdaitawi, 2020; Winne, 2022; Yoon et al., 2021), highlighting the necessity for further research aimed at enhancing students’ SRL in science education. The study implemented a SRFLA for a middle school science course, with an experimental process that included an e-book, video, and quiz components. This approach enabled students to read course content from an e-book, view instructional videos, answer online quizzes, and consult with the course instructor via an instant messaging program. In-class activities included small group discussions and feedback sessions with the instructor. The control group followed a traditional FL approach.

The initial findings of this study affirm that the FL approach positively influences the learning process of middle school students, corroborating recent studies in the field of science education (e.g., Candaş et al., 2022; Lee et al., 2021; Nacaroglu et al., 2023; Ugwuanyi, 2022). Further evaluation of the implemented SRFLA indicates a significant improvement in students’ academic achievements and an enhancement in their attitudes towards science. Moreover, the SRFLA also bolstered students’ SRL levels in areas such as goal setting, environment structuring, task strategies, time management, help-seeking, and self-evaluation. Additionally, this study furnishes empirical evidence highlighting the development of students’ motivations, encompassing intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy for learning and performance through this

approach. In alignment with Zimmerman and Schunk's (2011) core concepts, the findings suggest that middle school students were successful in activating and sustaining their affective, cognitive, and behavioral systems oriented towards the achievement of learning objectives in the science course.

The conduct of the study reinforces the enduring theories of Pintrich et al. (1991) and Duncan and McKeachie (2005), which advocate for the development of motivational orientations and the use of diverse learning strategies for science courses. These results are consistent with prior studies evaluating the impact of SRFL on students' learning processes (e.g., Çakıroğlu & Öztürk, 2017; Shibukawa & Taguchi, 2019; Shih & Huang, 2019; van Alten et al., 2020a; Zheng & Zhang, 2020). For instance, Lai and Hwang (2016) found that teaching in a self-regulated flipped classroom amplified students' learning achievements and self-regulated levels in a mathematics course. A comparable discovery by van Alten et al. (2020a) proposed that SRFL plays a pivotal role in enhancing students' learning and cultivating their awareness of their own learning process. A recent study by Kim et al. (2021) disclosed that SRL in the flipped classroom yields successful outcomes, ensuring student satisfaction and learning continuity.

In light of these findings, several practical implications can be derived to optimize science education, particularly in the context of evolving technology and the changing needs of students. Firstly, educators should consider incorporating SRFLA into their curriculum to improve students' learning outcomes. The use of e-books, instructional videos, and online quizzes in out-of-class activities allows students to control their learning and engage with the material at their own pace. Teachers can support this learning process by facilitating in-class activities, such as small group discussions, providing feedback, and creating a conducive learning environment. Additionally, teachers should emphasize the development of SRL skills in their students. Skills such as goal setting, environment structuring, task strategies, time management, help-seeking, and self-evaluation are crucial for students' academic success. By integrating these skills into the SRFLA, educators can help students become more independent learners who are capable of taking charge of their own learning experiences. The study also indicates the importance of fostering intrinsic and extrinsic motivations in students. Educators should strive to create engaging learning experiences that promote students' intrinsic goal orientation, task value, and self-efficacy for learning and performance. This can be achieved by incorporating interesting and relevant content, setting achievable yet challenging goals, and providing timely feedback and support. Furthermore, the study underlines the potential of technology in enhancing science education. As technology continues to advance, educators should stay updated on emerging tools and techniques that can support students' learning processes. By integrating technology into the SRFLA, teachers can create a more dynamic and interactive learning environment that caters to students' diverse needs and preferences.

5.1. Limitation and future studies

The present study, while contributing to our understanding, possesses certain constraints that future investigations should bear in mind. Its focus was exclusively on a single science topic, thereby inhibiting the generalizability of the results to other academic domains. Additionally, the selected sample comprised middle school students from a small city in Turkey, a decision informed by our intent to design specific learning environments and training support for this particular demographic. As such, it may not be appropriate to extrapolate these results to various learning contexts or to students of disparate age groups and cultural backgrounds. Owing to the paucity of studies in this area, future researchers should consider conducting their investigations with diverse student populations, considering varied backgrounds and age groups. In the current study, data collection relied on self-administered scales, a method that may introduce self-report bias. Therefore, researchers should exercise caution when employing Likert-type scales in their work and could consider supplementing their data with qualitative measurement tools to enrich the breadth and depth of their findings. While the current study yielded positive results, it is essential to note that the number of participants was relatively small and the application period only spanned a few weeks. These factors limit the study's efficacy and broader applicability. Thus, future studies involving larger participant groups and longer research durations would be of substantial value, potentially enriching the field with more comprehensive and generalizable findings.

5.2. Conclusions

While the flipped classroom approach is widely recognized as a potent tool for science education (Chen et al., 2022), its impact on SRL remains relatively unexplored. This study endeavored to fill this gap by integrating FL with SRL in the context of middle school education, employing a self-regulated flipped classroom approach, as proposed by Lai and Hwang (2016). The findings suggest that the application of FL fostered more effective

science learning when compared to the traditional pre-learning activity. Moreover, students instructed within a self-regulated flipped classroom exhibited greater academic success, more favorable attitudes towards science, higher levels of SRL, and enhanced motivation compared to their counterparts taught via traditional FL. A pivotal insight for science educators stemming from this study is that when students are actively involved in planning their learning process, they tend to demonstrate more effective learning outcomes. To support students' cognitive, metacognitive, affective, and motivational skills, diverse methods of in-class or out-of-class activities for SRFLA – such as setting learning goals and reflective practices – can be implemented.

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Students' strategy preference moderates effects of open or focused self-explanation prompts on learning from video lectures

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ABSTRACT: Previous studies have shown that encouraging students to use self-explanation strategies has proven effective in text-focused learning contexts. However, no study to date has focused on how students' strategy preference moderates the effect of self-explanation strategies on learning from video lectures. The current study investigated how students' self-explanation strategy preference impacts their learning from video lectures by using prompts with a between-within-subjects design strategy preference (i.e., strategy preference vs. no strategy preference; between subject) and with prompt type (i.e., focused vs. open; within-subject), assessing learning performance, cognitive load, attention allocation, quantity and quality of explanation, and behavioral patterns. Study results showed that, compared to students using open prompts and with no self-explanation preference, providing focused prompts improved their learning performance and explanation quality, lowering their cognitive load and enabling them to search for information more accurately. Meanwhile, for students with a self-explanation preference, the two types of prompts used in this study had a similar positive impact on their learning performance and their quality of explanation.

Keywords: Self-explanation, Strategy preference, Attention allocation, Behavior pattern

1. Introduction

Educators and researchers have long recognized that, although students can learn from viewing videos passively, they fare much better by learning actively, such as by self-explanation (Chi & Wylie, 2014; Fiorella & Mayer, 2015; Fiorella & Mayer, 2016; Pi et al., 2021). self-explanation refers to the generating of verbal statements to clarify the meaning of the learning material to oneself, which is commonly regarded as a beneficial strategy to enhance learning in a wide variety of settings (e.g., face-to-face education, text-based learning, video; Chamberland & Mamede, 2015; Pi et al., 2021; Van Lehn et al., 1992). For example, Pi et al. (2021) found that compared to passive viewing of video lectures, encouraging students to explain the video learning content to themselves led to a better learning performance.

When students generate self-explanation, they must first focus on the relevant incoming information, then retrieve the contents of the previously learned material from their memory to recognize what information is missing as they generate inferences before integrating information into a coherent structure to relate this new information to their prior knowledge, and then identify and correct the information received (Chi, 2000; Fiorella & Mayer, 2015; Fiorella & Mayer, 2016). Based on generative learning theory and the retrieval hypothesis, self-explanation assists students in retrieving information from memory which can foster learning through a consolidation function, and the processes involved in making inferences help students actively make sense of their learning (Fiorella & Mayer, 2016; Roscoe & Chi, 2008; Waldeyer et al., 2020).

However, many students do not innately engage in effective self-explanation (Berthold et al., 2009; Renkl, 1997). This suggests that self-explanation prompts should be designed to encourage self-explanation. self-explanation prompts refer to requests or directions given to the students that require them to process the learning contents in a specific way (Renkl, 2005). In recent years, self-explanation prompts have become used more broadly (Atkinson et al., 2003; Nokes et al., 2011; O'Neil et al., 2014). However, the understanding of the effects and mechanisms of self-explanation prompts is not yet fully understood (De Koning et al., 2011). It could be that the effects of self-explanation can vary according to the type of self-explanation prompt in combination with one's individual preference of learning strategy. To better understand this, the current study focused on how different types of self-explanation prompts impact students' learning, and whether the effect of the prompts is moderated by individual differences (i.e., self-explanation strategy preference).

1.1. Self-explanation prompts

Previous studies have generally used two types of self-explanation prompts: open and focused (Ainsworth & Loizou, 2003; De Koning et al., 2011; Wylie & Chi, 2014). The open self-explanation prompt allows students to make any form of connection between the given information and their existing knowledge. In contrast, the focused self-explanation prompt guides students' thinking about the material and helps them generate explanations to better understand it by providing scaffolds related to the content (Wylie & Chi, 2014).

The open self-explanation prompt has been widely explored in existing studies (Ainsworth & Loizou, 2003; De Koning et al., 2011; Wylie & Chi, 2014) and has been proven to be more effective on students' learning performance than using no prompt at all (Lachner et al., 2021a). For example, Lachner et al. (2021a; Experiment 2) found that, compared to the control condition, students in the open self-explanation condition demonstrated a better transfer of information.

Existing studies suggest that providing more specific explanations via focused self-explanation prompts facilitates learning better than open self-explanation prompts (Wylie & Chi, 2014; Renkl, 2002). Kirschner et al. (2006) suggest that, compared to open prompts, focused self-explanation prompts may be more beneficial for learning because focused self-explanation prompts can provide stepping stones that help students' avoid erroneous understandings which can happen during self-explanation activities. For example, Berthold et al. (2009) found that, compared to an open self-explanation prompt, a focused one could enhance students' procedural knowledge and conceptual understanding.

More importantly, the scaffold of the key words in the focused self-explanation prompts can act as text cues for video learning. These key words can help students reduce their cognitive load and allocate their attention to specific content while reducing redundant search behaviors. Nivala et al. (2012) inferred that text cues can direct students to focus on the most obvious pitfalls and thus improve their learning performance compared to no text cues. However, their study did not collect eye-movement data as evidence.

Kwon et al. (2011) found that students in the open self-explanation condition outperformed those in the focused self-explanation condition in a debugging task, and demonstrated higher confidence levels in their explanations. The researchers proposed that open self-explanation prompts allowed the students to find solutions to problems by themselves, helping them to reflect further on their explanations. In contrast, the focused self-explanation prompts might have forced students to make sense of the provided information in one specific way, thus hindering their ability to generate inference.

Inconsistent results such as these could be due to individual differences. Aleven et al. (2006) found that the effects of focused and open self-explanation prompts on law-learning differed depending on student type: for the less-capable students (as measured by their Law School Admissions Test results), the advantages of a focused prompt outweighed those of the open self-explanation prompt, while the more-capable students (also according to their Law School Admissions Test results) learned better when using open self-explanation prompts. This result suggests that different prompt types can benefit students in numerous ways.

In addition to students' academic abilities, individual preference is also closely related to the effectiveness of particular learning strategies (Lachner et al., 2021a; Lachner et al., 2021b). It appears that the more preference a student has for a particular strategy, the more beneficial that strategy will be for that student (Shih, 2011; Yu, 2011). Unlike Aleven's et al. (2006) study which focused on students' academic abilities, the current study thus focused on individual differences in strategy preference.

1.2. Self-explanation strategy preference

Learning strategies are the techniques or skills that an individual elects to use in order to accomplish a learning task (Fellenz & Conti, 1989). Thus, strategy preference refers to a student's usage of particular learning strategies when participating in a learning activity (Conti, 2009; Vos et al., 2011), which is shown to be closely related to their learning (Vos et al., 2011). Conti and McNeil (2011) used the Assessing The Learning Strategies of AdultS questionnaire (ATLAS) and found that there are three groups of learning strategy preference (i.e., navigators, problem solvers, and engagers) and they were differ in how they process learning information and accomplish the learning task (i.e., navigators and problem solvers searched the information from the externally, whereas the engagers prefers the internally reflect). In addition, a study conducted by Eielts et al. (2020) found that, compared to students who did not have a preference towards the gesture strategy (i.e., have no propensity to use gestures spontaneously), students who preferred this strategy completed the Tower of Hanoi problem-solving

tasks quicker. Considering the present learning context focused only on short-term learning, the present study adopted the Eielts' et al. (2020) ways and defined the self-explanation strategy preference as whether students had the propensity to use the self-explanation strategy spontaneously.

Students with or without self-explanation a strategy preference might learn differently naturally. Specifically, students with a preference for self-explanation will have the propensity to use the self-explanation strategy, which means first they will hold more positive beliefs about the benefits of self-explanation. They will be more familiar with the usage of strategy, which can help them seek out related learning materials much quicker during their explaining process. The strategy familiarity can also lower their cognitive load and allow them more working memory resources to be dedicated to explaining (Kalyuga & Singh, 2016). In contrast, students who use the self-explanation strategy less might worry about how to use it, thus increasing their cognitive load during the exercise.

As both prompt type and the use of the self-explanation strategy are assumed to influence students' leaning performance and cognitive load, it is therefore reasonable to assume that these would have an interactive effect in video learning. Specifically, students with no self-explanation strategy preference might benefit much more from using focused prompts to construct their explanations because it provides them with key words on which to scaffold, as opposed to open prompts. Still, the effects might be reverse for students with a self-explanation strategy preference.

1.3. The present study

Existing studies have primarily examined the positive effect of self-explanation in comparison to passive learning regarding text-based lessons (Lachner et al., 2021a; Lachner et al., 2021b) rather than on learning from video lectures. Video lectures differ from text-based lessons because the transient information in the video lectures can be more challenging for students to process if they do not use appropriate learning strategies. That is to say, the positive effect of self-explanation on learning may exist across contexts, or even be more beneficial in one particular context over another. However, students cannot spontaneously engage in effective self-explanation without prompts. Given the rapid increase in the use of video lectures in both formal and informal learning settings, it is essential to determine the effectiveness of and which type of self-explanation prompts will best suit students' strategy preferences.

The current study aimed to examine whether different types of self-explanation prompts and students' strategy preferences would independently and interactively affect learning from video lectures. A 2 x 2 between-within subjects design with prompt type (i.e., focused vs. open; within subject) and strategy preference (i.e., strategy preference vs. no strategy preference; between subject) was used in the present study.

With regards to the self-explanation prompts, we chose two of the more commonly-used types: open, in which students are encouraged to generate their own explanations, and focused, in which students are given keywords and information which then guides them in generating an explanation (Wylie & Chi, 2014). In both conditions, students were required to generate an oral explanation, as has been commonly done in previous studies (Jacob et al., 2020; Pi et al., 2021). For the self-explanation preference and the no self-explanation preference samples, we chose student participants for the two categories according to who indicated a preference for the self-explanation strategy when watching a video lecture during a screening study.

Previous studies on the explaining activity have always tested outcomes such as learning performance (Ainsworth & Loizou, 2003; De Koning et al., 2011; Wylie & Chi, 2014) rather than the learning processes, such as attention allocation or viewing behavior patterns. However, according to generative learning theory, explaining can benefit students when selecting, organizing, and integrating information relevant to the learning processes. Thus, in the present study, by examining the mechanisms underlying the effects of prompt type and self-explanation preferences, we focused not only on students' learning outcomes, but also their learning processes. We tested learning processes based on their attention allocation to the video lectures and the explanation prompts as measured by eye-tracking, as well as by assessing their explanation quality and their video viewing behavioral sequences as measured by log data. Previous studies have found that behavioral sequences are closely related to students' individual differences such as their learning preferences (de Boer et al., 2011; Kay, 2012) and learning performances (de Boer et al., 2011; Li, 2019) and can therefore reveal how students process information.

Altogether, we hoped that the outcome variables might explain why certain types of prompts benefit certain students. The current study investigated the following research questions:

- Q1: Are there any significant differences in students' learning performance with or without a self-explanation strategy preference when they receive either open or focused self-explanation prompts during video lecture learning?
- Q2: Are there any significant differences in participants' reported cognitive load with or without a self-explanation strategy preference when students receive either open or focused self-explanation prompts during video lecture learning?
- Q3: Are there any significant differences in the attention students allocate to the content or prompt areas of the screen during video lectures according to whether they do or do not have a self-explanation strategy preference, and is this influenced by whether they receive either open or focused self-explanation prompts?
- Q4: Are there any significant differences in students' explanation quality after video lecture learning according to whether they do or do not have a self-explanation strategy preference, and is this influenced by whether they receive open or focused self-explanation prompts?
- Q5: Are there any significant differences in students' behavioral patterns during video lecture learning according to whether they do or do not have a self-explanation strategy preference, and is this influenced by whether they receive open or focused self-explanation prompts?

2. Method

2.1. Participants

An a priori power analysis conducted with G*Power ($f = 0.25$, $\alpha = 0.05$, power = 0.95, number of groups = 2, number of measurements = 2), showed that $N = 54$ would be a sufficient sample size for the planned analyses. We enrolled 75 participants via advertisements. Because of failure to pass the experiment screening (i.e., consistency as to whether they exhibited self-explanation behavior during the screening combined with their reported strategy preference; Stage 1: 11 students) and eye-tracking calibration (4 students), a total of 15 participants were excluded, yielding a final sample of 60 participants in the data analysis (Mage = 21.55, $SD = 2.23$, 17–26 years; 20 males). All participants had normal or corrected vision and normal hearing. Everyone provided their written informed consent and received 40 CNY for their participation.

2.2. Video lectures

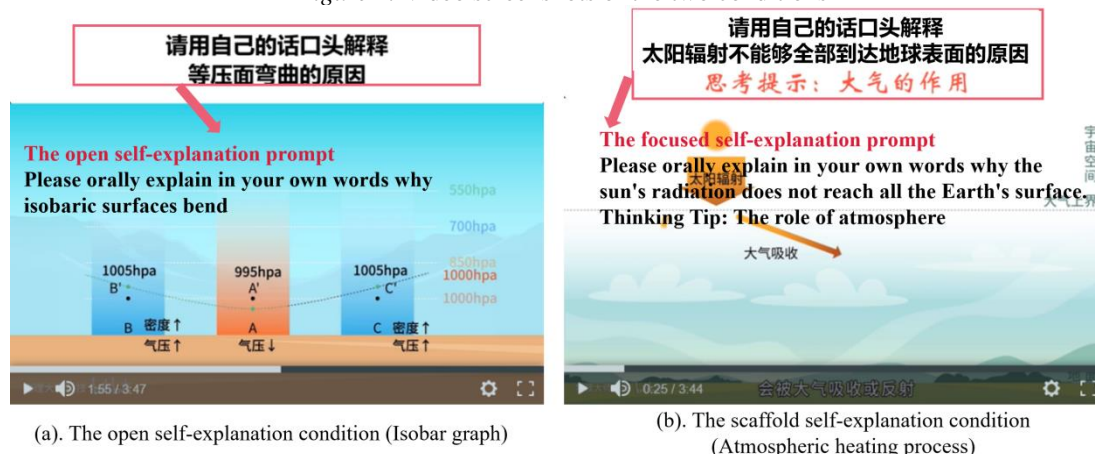
Three video lectures were used in this study. The first video lecture was used to distinguish whether participants would use self-explanation strategies spontaneously, that is, to judge participants' preferences for self-explanation strategies. The topic of the video lecture was “the blood circulatory system” (https://www.bilibili.com/video/BV1o741157kv?spm_id_from=333.788.b_636f6d6d656e74.7), which explained the structure of the heart and the process of the human systemic circulation and pulmonary circulation. The video lecture lasted 2 minutes and 23 seconds.

The other two video lectures were designed for the two conditions, with students receiving either open or focused self-explanation prompts. To ensure that the two video lectures were the same level of difficulty, addressed the same knowledge types, and were unique, two topics relating to geography as recommended by two professors were selected: “the atmospheric heating process” and “isobaric graphs.” The atmospheric heating process video explained the process using three aspects: solar radiation, ground radiation, and atmospheric radiation. The isobaric graph video lecture explained the concept of an isobaric surface, the process of isobaric surface change, and the concept of a pressure line. Both videos were edited using Camtasia Studio 9 software to keep the video durations relatively similar. The atmospheric heating process video was 3 minutes and 38 seconds long, and the isobaric graphs video was 3 minutes and 41 seconds long.

To determine that the two video lectures were homogenous, we recruited 20 graduate students majoring in geography to evaluate them. After watching each of the two videos, the graduate students answered two questions: “I think the difficulty of the video is [ranking the video from 1 = easy to 5 = difficult],” and “I think the type of knowledge of the instructional video is: A. Declarative knowledge (concepts, propositions, and factual knowledge) or B. Procedural knowledge (knowledge related to specific skills and processes).” No significant difference was reported in the perceived difficulty of the two instructional videos ($t[20] = 1.00$, $p = .330$), nor was there any significant difference noted in the type of knowledge ($\kappa = 1.00$). Therefore, the two videos were determined to be homogenous.

We then invited two graduate students proficient in relevant knowledge to design the prompt content for the self-explanation strategies (see Figure 1). The “isobaric graph” video lecture was designed to be the open self-explanation prompt condition. In this condition, the prompts noted only the requirement for self-explanation, asking participants to explain the learned content in a completely open format. For example, for the “isostatic surface” topic, the self-explanation prompt was, “Please orally explain in your own words why isobaric surfaces bend.” Meanwhile, the “atmospheric heating process” video lecture was designed to be the focused self-explanation prompt condition. In this condition, the prompt content not only included the requirement for self-explanation, but also included scaffolds. For example, for “atmospheric inverse radiation,” the self-explanation prompt was, “Please orally explain in your own words why the sun’s radiation does not reach all of the Earth’s surface,” with a scaffold presented simultaneously on-screen below the self-explanation prompt, titled “Thinking Tip: The Role of the Atmosphere.”

Figure 1. Video screenshots of the two conditions



To encourage participants to pay attention to the prompts during the videos, we set up a “viewing reminder” before the video began to play. The prompt content was, “During the video learning, please follow the prompts located in the upper part of screen which will ask you to explain the information to yourself. The video is self-paced.” We designed six prompts for each video, and the prompts were shown for a total of about 1 min 30s for the isobar graph video, and for 2 mins for the atmospheric heating process video. Participation was self-paced, and students were free to control the video by fast forwarding, pausing, rewinding, and playing it at normal speed.

2.3. Measurements

Measurements used included a demographics questionnaire, a prior knowledge test, a learning performance test, a cognitive load questionnaire, a coding scheme for participants’ explanations, and a coding scheme for participants’ viewing behavioral sequences.

2.3.1. Demographics questionnaire

Participants were asked to provide their age, gender, study major, and grades.

2.3.2. Prior knowledge performance

The prior knowledge test was used to ensure that all student participants, with or without a self-explanation strategy preference, had a similar level of knowledge on the two video topics. It consisted of 10 items, with five items focusing on the atmospheric heating process and five on the isobar graph. The total possible prior knowledge score was 10 (atmospheric heating process Cronbach’s $\alpha = .66$; isobaric graph Cronbach’s $\alpha = .47$). No significant differences in prior knowledge performance on the two topic conditions were seen between the two groups ($F[1, 58] = 0.03, p = .876$).

2.3.3. The learning performance test

Learning performance for the atmospheric heating process video was assessed using a test comprising nine items: six multiple-choice items and three fill-in-the-blank items (eight blanks in total). The total possible test score was 20 points (Cronbach's $\alpha = .44$). The test used to assess learning performance for the isobaric graph video comprised seven items in total: three multiple-choice items, three fill-in-the-blank items (six blanks in total), and one short-answer item. Two trained assessors rated the short-answers separately and gave a score ranging from zero to six points. The intra-class correlation coefficient (ICC) was .969, indicating that agreement between the two assessors was quite satisfactory. The total possible test score was 20 points (Cronbach's $\alpha = .66$).

2.3.4. Cognitive load questionnaire

Two items adapted from Van Merriënboer et al. (1992) and Deleeuw and Mayer (2008) were used to assess participants' cognitive load. The questionnaire consisted of two nine-point Likert-scale questions which assessed the degree of task difficulty and the mental effort involved in learning. This questionnaire has shown high reliability in previous studies (Van Merriënboer et al., 1992) and has been widely used to measure mental effort (Hong et al., 2018).

2.3.5. Coding explanation quality

The oral explanations generated by the participants in response to the video prompts were collected using a IFLYTEK intelligent recording pen (SR502). The recordings were coded immediately according to two considerations: concepts and elaborations. Concepts refers to the number of concepts generated by the participant, which is an indicator of their level of comprehension (Fiorella & Kuhlmann, 2020; Jacob et al., 2020). The total core concepts for each topic were ten, thus the maximum score for concepts in the current study was ten. Elaborations refers to the number of generated explanations that went beyond the learning materials by participants integrating their prior knowledge with what they had just learned (Fiorella & Kuhlmann, 2020; Lachner et al., 2018). These answers were rated separately by the two trained assessors. The ICC was 0.903, indicating that the agreement between the two raters was quite satisfactory.

2.3.6. Coding viewing behavioral sequences

To assess participants' viewing behavioral sequences while watching the video lectures, a video viewing behavior coding scheme was used. Adapted from Li (2019), eight actions were defined which related to video viewing strategies (see Table 1). The coding scheme was developed with consideration of findings from existing literature as to how to best enhance validity (Li, 2019; Sinha et al., 2014). To confirm the validity of the developed coding scheme, two trained raters checked and verified its feasibility. The two assessors worked together to code the first five participants' behavior, assessing 65 behaviors in total, and the inter-rater reliability was Cohen's Kappa = 0.982. Discrepancies between coding were solved through discussion. After that, participant behaviors were each coded by one assessor. An example of the coding is as follows: if a student paused the video, then thought in silence before clicking on the video section to continue playing the video, the coding would be "Pa Ts Pl." Thus, a full sequence of coded behavior for a participant could have been: "Pa Ts Pl Sf Pa Ts Pl Sf Pa Se Pl Pa Se Se Se Se."

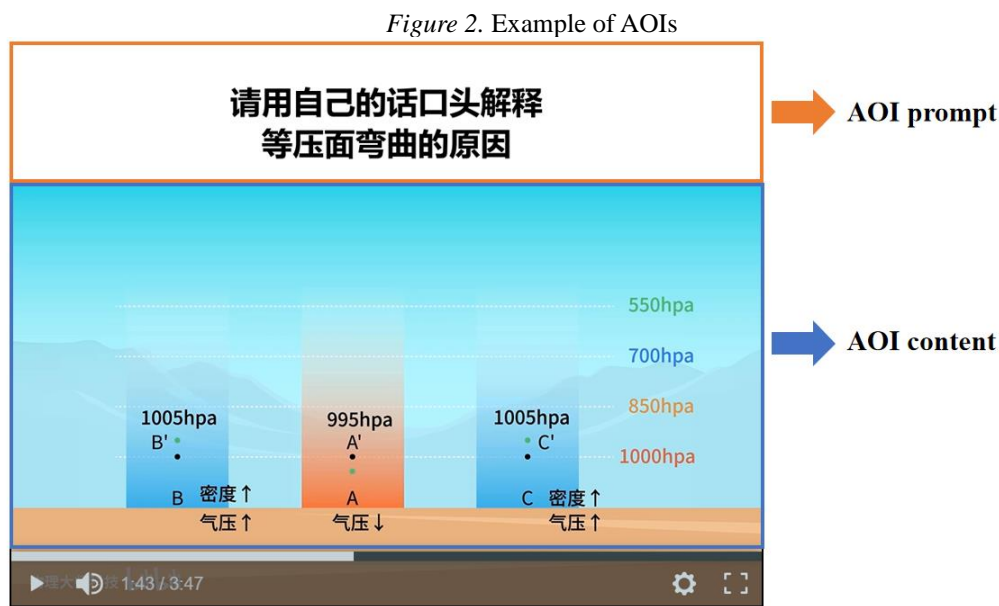
Table 1. Coding scheme of video viewing behavior

Behavior	Coding	Descriptions
Play	Pl	Participant clicked the video section to play the video.
Pause	Pa	Participant clicked the video section to pause the video.
Seeking forward	Sf	Participant clicked the play bar to jump to a later time point.
Seeking Backward	Sb	Participant clicked the play bar to jump to a previous time point.
Replay	Rp	After the video finished, participant clicked the replay button to re-play the video again from the beginning.
Self-explaining	Se	Participant self-explained content out loud using self-explaining prompts.
Thinking aloud	Ta	Participant thought out loud on any topic.
Thinking in Silence	Ts	Participant paused the video to think for five seconds or longer.

2.4. Apparatus

Eye movements were recorded using a Tobbi T120 eye tracker with a sampling rate of 120 Hz. We chose the Tobbi T120 because it allows us to use the video as stimulation while being easy to use, and did not require that the participant's head be fixed, allowing for use under natural conditions. However, because the eye-movement was captured under natural conditions, some participants' eye-tracking data could have been lost if they shook severely while watching the video. Four participants' data was deleted in the present study due to having lost over 40% of their eye-movement data. The video was presented on a monitor with a 1920 x 1440 pixels resolution. Participants listened to the lecture audio using headphones connected to the computer.

Two areas of interest (AOI; see Figure 2) were created on the instructional video screen, one corresponding to the content area and one to the prompt area, to analyze the effect of the self-explanation prompts on participants' attention allocation. Attention allocation was measured by the percentage of time participants spent dwelling on each AOI.



2.5. Procedure

The experiment was divided into two stages: preparation and formal (see Figure 3). In the preparation stage, the aim was to select suitable participants. In the formal stage, we used a mixed experimental design (within-subjects: open prompts vs. focused prompts; between-subjects: self-explanation preference vs. no self-explanation preference) to test whether the self-explanation prompts affected participants differently depending on their strategy preference.

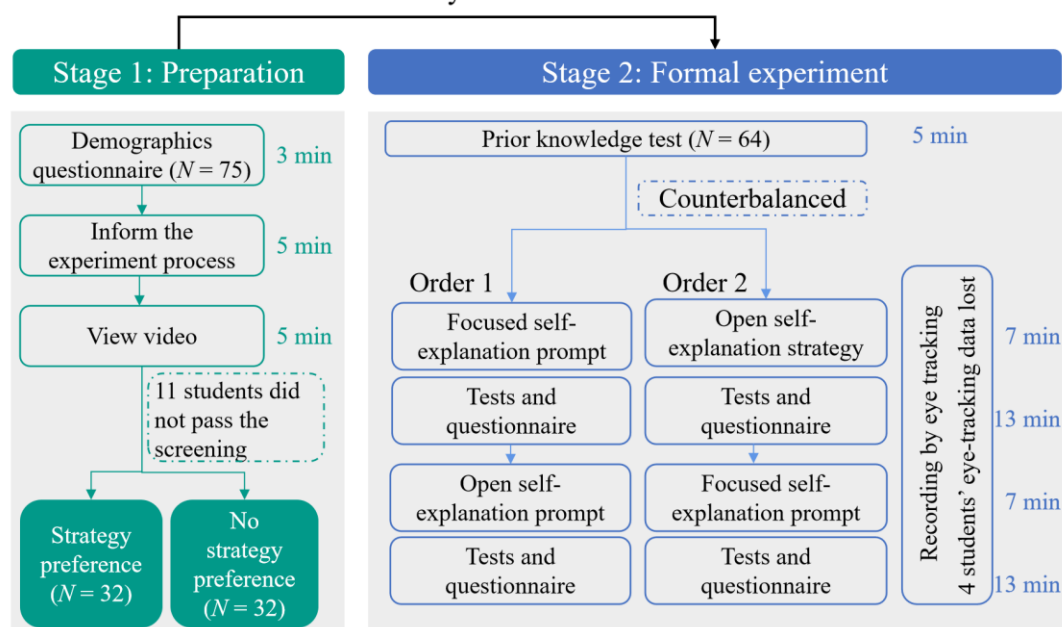
In the preparation stage, participants were first told the experiment process and given the following prompt: "Learning by self-explanation is a useful strategy whereby students generate explanations to clarify the lessons being taught through the learning materials, integrating information from various sources and relating it to their already-existing knowledge. While watching this video, you are free to use the self-explanation strategy, but if you use it, you must speak out loud." Participants were then shown the video lecture about blood circulation. The entire process was recorded using the EV screen recording software.

Afterward, they were asked informal questions about whether they preferred using the self-explanation strategy or not in their own studies. Then, by checking the recordings taken while they watched the preparation stage video, participants were divided into two groups – preference for the self-explanation strategy or no preference for the self-explanation strategy – according to whether they exhibited self-explanation spontaneously in combination with their responses to the informal questions. Students who had exhibited self-explanation spontaneously while watching the video lecture and had reported that they preferred the strategy were placed in the "self-explanation strategy preference" group. Those who did not exhibit any self-explanation and answered that they did not prefer the self-explanation strategy were placed in the "no self-explanation strategy preference" group. Students who did exhibit self-explanations but replied that they did not prefer the self-explanation

strategy to the informal questions as well as those who did not exhibit any self-explanations but did report liking the strategy were not invited to participate in the next stage of the study due to the inconsistency between their behavior and responses. A total of 11 students were excluded at this point.

The formal stage of the study took place two days after the preparation stage, after the participants had been allocated into cohorts. The remaining 64 participants were invited to an eye-tracking laboratory for the next stage, and the experiment lasted approximately 50 mins. First, all participants completed the demographic questionnaire and the prior knowledge test. Then, they were informed that they would view two instructional videos, one with open self-explanation prompts and one with focused self-explanation prompts. They were told that the exercise would be self-paced and that they would need to participate in the self-explanation orally. They were also told that afterward they would take a test about the information they learned from the videos they were about to watch. The video view order was counterbalanced, with 32 participants viewing the focused self-explanation prompt condition video first, followed by the open self-explanation prompt (Order 1), and the other 32 participants viewing the videos in the reverse order (Order 2). After a five-point calibration and validation, each participant viewed the two videos consecutively as their eye-tracking and clicking behaviors were recorded. Immediately after viewing the videos, the participants completed the cognitive load questionnaire and the learning performance test (see Figure 3). Due to missing eye-movement data, four students were excluded at this point.

Figure 3. Diagram of the procedure
Two days later



2.6. Data analysis

Data from the final sample of 60 participants were used for all analyses. Repeated measures ANOVAs were conducted to assess the differences between the groups and conditions. Prompt type (i.e., focused vs. open) and strategy preference (i.e., self-explanation preference vs. no self-explanation preference) were used as independent variables. The same repeated measures ANOVA was used for the four dependent variables.

3. Results

Descriptive statistics for the dependent variables are outlined in Table 2. Primarily analysis on the correlation across all the variables was conducted (see Appendix). The results showed that participants in the Open Prompt + Self-Explaining Preference group showed a positive correlation between the prior knowledge performance and elaborations, and learners in the Open Prompt + No Self-Explaining Preference showed a positive correlation between the prior knowledge performance and learning performance.

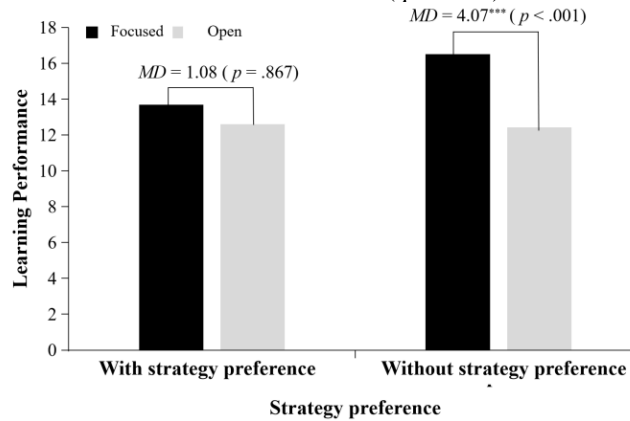
Table 2. Means of all dependent variables with standard deviations in parentheses

Dependent variable	Self-explanation preference		No self-explanation preference	
	Focused	Open	Focused	Open
	<i>n</i> = 30 <i>M</i> (<i>SD</i>)	<i>n</i> = 30 <i>M</i> (<i>SD</i>)	<i>n</i> = 30 <i>M</i> (<i>SD</i>)	<i>n</i> = 30 <i>M</i> (<i>SD</i>)
Prior knowledge performance	3.83 (2.44)	3.40 (2.24)	3.80 (2.61)	3.47 (2.57)
Learning performance	13.68 (4.65)	12.60 (5.29)	16.50 (2.47)	12.43 (4.75)
Cognitive load	9.10 (1.99)	9.87 (2.22)	10.17 (2.17)	10.77 (1.96)
Percentage of dwell time on prompt	8.61 (5.21)	5.49 (3.29)	9.16 (4.83)	5.74 (3.33)
Percentage of dwell time on content	43.64 (12.09)	53.21 (11.16)	43.73 (14.33)	50.53 (16.28)
Concepts	4.17 (2.00)	4.30 (1.56)	4.03 (2.09)	4.20 (2.30)
Elaborations	3.14 (1.02)	3.35 (1.09)	2.97 (1.27)	2.48 (1.16)

3.1. Learning performance

To investigate Q1, we examined whether the explanation type and strategy preference influenced participants' learning performance. Results showed a significant main effect of prompt type ($F[1, 58] = 17.63, p < .001, \eta_p^2 = 0.23$) and a significant interaction effect ($F[1, 58] = 5.92, p = .018, \eta_p^2 = 0.09$), but no main effect of strategy preference ($F[1, 58] = 1.89, p = .175, \eta_p^2 = 0.03$; see Figure 4) on learning performance. The interaction effects showed that participants who had no explanation strategy preference showed a higher learning performance in the focused prompt condition than they did in the open prompt condition (Mean Difference [MD] = 4.07, $p < .001$). For those with a strategy preference, however, the results were similar whether they used the open or focused prompts ($MD = 1.08, p = .867$).

Figure 4. Differences between the four conditions in learning performance. Significant differences between conditions are marked (* $p < .001$)



3.2. Cognitive load

To investigate Q2, we examined whether prompt type and strategy preference influenced participants' cognitive load. The results showed main effects on prompt type ($F[1, 58] = 7.65, p = .008, \eta_p^2 = 0.12$) and strategy preference ($F[1, 58] = 4.21, p = .045, \eta_p^2 = 0.07$), but no interaction effect ($F[1, 58] = 0.11, p = .737, \eta_p^2 = 0.002$). Participants in the focused prompt condition reported a lower cognitive load than those in the open prompt condition ($MD = 0.68, p = .008$). Those with a strategy preference reported a lower cognitive load than those with no strategy preference ($MD = 0.98, p = .045$).

3.3. Attention allocation

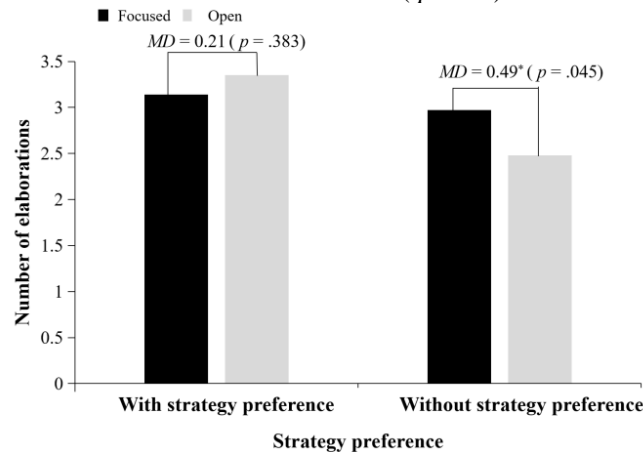
To investigate Q3, we examined whether the prompt type and strategy preference influenced participants' attention allocation concerning the explanation or content areas. For the dwell time on the explanation area, the results showed that there was a main effect on the type of prompt ($F[1, 58] = 32.06, p < .001, \eta_p^2 = 0.356$) but no main effect on strategy preference ($F[1, 58] = 0.19, p = .667, \eta_p^2 = 0.003$) nor interaction effect ($F[1, 58] = 0.07, p = .796, \eta_p^2 = 0.001$). Participants in the focused prompt condition showed a higher percentage of dwell time on the prompt area than those in the open prompt condition ($MD = 3.27, p < .001$).

For the dwell time on the content area, the results showed that there was a main effect on the prompt type ($F[1, 58] = 55.01, p < .001, \eta_p^2 = 0.48$) but no main effect on strategy preference ($F[1, 58] = 0.15, p = .699, \eta_p^2 = 0.003$) nor interaction effect ($F(1, 58) = 1.57, p = .215, \eta_p^2 = 0.03$). Participants in the focused condition showed a lower percentage of dwell time on the content area than those in the open condition ($MD = 8.18, p < .001$).

3.4. Explanation quality

To investigate Q4, we examined whether the prompt type and strategy preference influenced participants' concepts and elaborations. For the number of concepts, the results showed that there was no main effect (prompt type: $F[1, 58] = 0.26, p = .610, \eta_p^2 = 0.005$; strategy preference: $F[1, 58] = 0.075, p = .786, \eta_p^2 = 0.001$) nor any interaction effect ($F[1, 58] = 0.003, p = .955, \eta_p^2 < 0.001$; see Figure 5).

Figure 5. Differences between the four conditions in explanation quality. Significant differences between conditions are marked (* $p < .05$)



For the number of elaborations, the results showed that there was a main effect on participants' strategy preference ($F[1, 58] = 4.64, p = .035, \eta_p^2 = 0.07$) and an interaction effect ($F[1, 58] = 4.28, p = .043, \eta_p^2 = 0.07$), but no main effect on the prompt type ($F[1, 58] = 0.68, p = .413, \eta_p^2 = 0.01$). The interaction effects showed that participants who did not prefer the explanation strategy generated lower quality explanations in the open prompt condition than they did in the focused prompt condition ($MD = 0.49, p = .045$), but for those with a strategy preference, the effect of receiving either the focused or open prompts was similar ($MD = 0.21, p = .383$).

3.5. Viewing behavioral sequences

To investigate Q5, we examined whether prompt type and strategy preference influenced participants' watching behavior sequences. The viewing behavioral sequences were recorded under all four conditions. Significant behavior sequences are depicted in Figure 6. According to Figure 6, for those who preferred self-explanation, focused prompts produced 13 significant behavioral sequences, whereas open-ended prompts produced only nine significant behavioral sequences; for those who did not prefer self-explanation, participants using focused prompts produced 11 significant behavioral sequences, while using open-ended prompts also produced 11 significant behavioral sequences. Based on these results combined, however, participants demonstrated more significant viewing behaviors sequences when using focused prompts (i.e., 24) than when using open prompts (i.e., 20; see Figure 6).

Participants who preferred the self-explanation strategy as well as those who did not prefer the self-explanation strategy in both the focused and open prompt conditions all showed some similar behavioral patterns. For instance, the behavior sequences of Pa→Ts→Pl and Pa→Se→Pl indicate that the learner would pause the video and then fall into silence to think or self-explain before continuing to play the video. As the video exercise was self-paced, participants were able to pause the video anytime they wanted. Therefore, the reason for such behavior sequences could have been that participants were afraid to miss information in the video, and chose to pause the video to think through the information and use self-explanation techniques before continuing to watch the lecture.

Figure 6a. Focused prompt + self-explanation preference

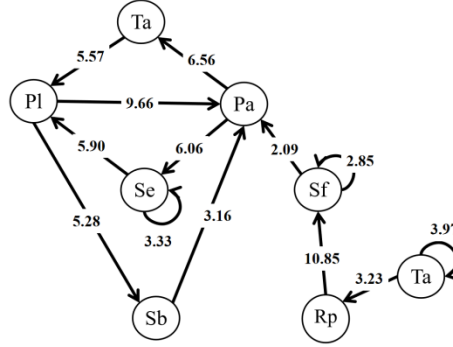


Figure 6b. Open prompt + self-explanation preference

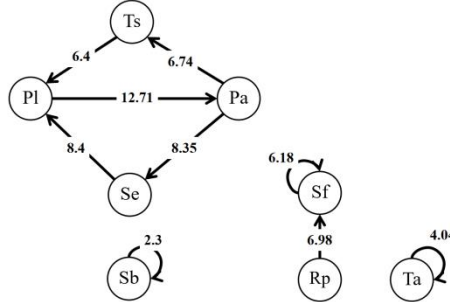


Figure 6c. Focused prompt + no self-explanation preference

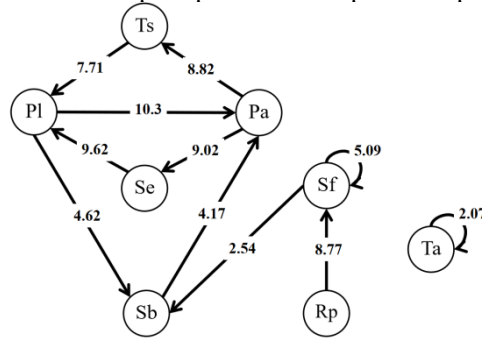
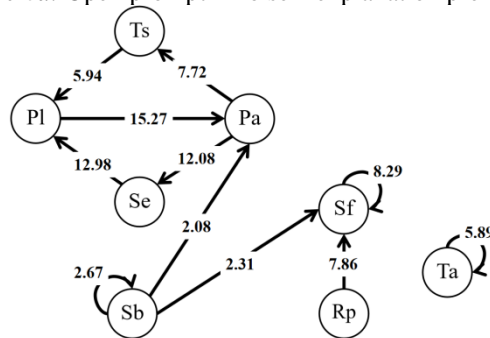


Figure 6d. Open prompt + no self-explanation preference



There were also differences in behavioral sequences between the open and focused prompt conditions for participants from both strategy preference groups as well. Those who preferred the self-explanation strategy exhibited more significant behavior sequences (Pl→Sb, Se→Se, Sf→Pa, Ta→Rp) in the focused prompt condition, but a less significant frequency of the Sb→Sb behavior patterns when compared to in the open prompt condition, indicating that for those with a preference for self-explanation strategies, focused prompts enable them to better reflect and consider the information, in that they paused more and demonstrated more self-explanation behavior.

As for participants with no preference for self-explanation strategies, those in the focused prompt condition exhibited more significant behavioral sequences (Pl→Sb, Sf→Sb) and less significant behavioral sequences of Sb→Sb and Sb→Sf compared to when in the open prompt condition, indicating that for those with no self-explanation strategy preference, focused prompts caused them to engage in more self-reflective behavior with regards to what they had already viewed, rather than searching between parts of the video lectures at a later point.

4. Discussion

The present study focused on the interaction effects of the type of self-explanation prompts and one's self-explanation strategy preference on learning from video lectures, as assessed by learning performance, cognitive load, attention allocation, quality of explanation, and viewing behavioral sequence patterns. The results showed that for those with no self-explanation strategy preference, focused prompts can help them improve their learning performance and explanation quality, allowing them to seek information more effectively than when offered open prompts. Meanwhile, for those who preferred a self-explanation strategy, both prompt types had a similar impact on both participants' learning performance and their explanation quality. The study advances our understanding of self-explanation prompts and self-explanation preference by providing the outcome and processes-related variables.

We discovered that having a strategy preference moderated the effect of focused prompts on learning performance and explanation quality more so than for the open prompts. Meanwhile, for participants with no strategy preference, their learning performance and explanation quality improved more in the focused prompt condition than in the open prompt condition. In contrast, participants with a self-explanation strategy preference showed no notable benefit in the focused prompt condition. This suggests that focused prompts can enhance learning performance better than open prompts for those with no strategy preference, which is consistent with previous findings (Berthold et al., 2009; Kirschner et al., 2006). The reason for this could be that those with no strategy preference may not be as capable of generating nonstructured self-explanations simply because they are not used to using the strategy. The focused prompts thus support and guide them in how to construct their explanations and reach their zone of proximal development, thus improving their learning abilities (Koedinger & Aleven, 2007).

In contrast, those with a self-explanation strategy preference are likely already familiar with the self-explanation strategy because they already have a tendency to use it (Conti, 2009; Vos et al., 2011). In this case, focused prompts offer no further benefit, although our findings show that these individuals reported lower cognitive load in the focused prompt condition than those who had no self-explanation preference. This could be why we did not find a significant difference in learning performance between the two groups.

Further behavior sequence analysis advances our understandings of the moderation effect and how students process video information. For those with no self-explanation strategy preference, focused prompts led to students producing more significant sequences of reflection and exhibiting increased effort to recall information (i.e., Pl→Sb, Sf→Sb), and fewer significant sequences of uncertain information searching (i.e., Sb→Sb, Sb→Sf). This may be why these participants showed increased learning ability in the focused prompt condition as compared to in the open prompt condition. These results are consistent with those of Giannakos et al. (2015), who found that the more meaningful the behavior sequences, the higher the learning performance. For those with a self-explanation strategy preference, although focused prompt condition led to a higher rate of significant behavior sequences (i.e., Pl→Sb, Se→Se, Ta→Rp, Sf→Pa), indicating that they were making more effort to recall or search for information, exhibiting more pauses, and self-explanation more than in the open prompt condition, these significant behavior sequences did not result in an improvement in participants' learning performance. This could be because the benefits of one's strategy preference outweigh the benefits of focused prompts overall, which did not further improve their self-explanation quality.

The eye movement data showed that, compared to the open prompt condition, participants in the focused prompt condition spent a lower percentage of dwell time on the video content and a higher percentage of dwell time on the prompt itself. This is reasonable because the prompt area included more information in the focused prompt condition. We did not observe any significant difference in dwell time between the strategy preference and no strategy preference groups. This could be due to two reasons: first, the video exercise was self-paced, and attention allocated to the information in the AOI would have been affected by the overall time spent on the entire exercise; second, we used only one index, which cannot fully represent attention allocation. Future studies

should use a more complex index to explore these differences, such as measuring individuals' blink rates which can represent participants' internal attention (Chermahini & Hommel, 2010).

Three limitations of this study should be acknowledged. First, the current study was conducted within a university context, but previous studies have shown that age influences the impact of the explaining effect because as we grow older, our knowledge, learning strategies, cognitive capacities, and metacognitive abilities also increase (Brod, 2020; Hilton et al., 2021). Meanwhile, a meta-analysis by Brod (2020) exploring the age-related explaining effect, and found that the positive effect decreases with age. Future studies should use samples of different age groups to determine whether the effects of the two prompt types vary according to an individual's age.

Second, the measurement of the self-explanation strategy preference in the current study was tentative and differed from the measurement of the ATLAS as used in previous studies (Conti, 2009; Conti & McNeil, 2011). Researchers have used ATLAS to categorize learners' learning strategy preferences into three groups: navigators, problem solvers, and engagers. Considering the present learning context focused only on short-term learning, we did not use the ATLAS. Furthermore, the present measurement might be limited because it could have been influenced by many factors, such as students' prior knowledge, motivation, and personality. Although we controlled all the confounding factors through random sample selection, future studies should investigate a better way to avoid these factors and develop a more valid measurement for short-term learning.

In conclusion, the main finding of the current study is that strategy preference moderates the effect of both open and focused prompts on learning performance and behavior sequence. Our results show that, for those with no self-explanation preference, providing focused prompts rather than open prompts as a part of the teaching-by-video process could improve students' learning performance as well as explanation quality, while lowering their cognitive load and guiding them more effectively in searching for information. Meanwhile, for those with a self-explanation strategy preference, both types of prompts had a similar impact on learning performance and explanation quality. Our findings have practical implications for learning from videos: it is better to provide a survey for learners to identify whether they have the preference of the strategy, and then if students already have a tendency to use the self-explanation strategy (strategy preference), there is no need to provide them focused or open self-explanation prompts; however, if students do not already adopt the self-explanation strategy, it is better to provide them with focused self-explanation prompts to improve their learning from videos.

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Appendix

Table A1. The correlations in focused prompt + self-explaining preference condition

	1.00	2.00	3.00	4.00	5.00	6.00
1 Prior knowledge performance	1.00					
2 Learning performance	0.29	1.00				
3 Cognitive load	-0.32	0.07	1.00			
4 Percentage of dwell time on prompt	-0.06	-0.02	-0.20	1.00		
5 Percentage of dwell time on content	-0.06	-.423*	-0.07	0.34	1.00	
6 Concepts	0.03	0.27	-0.02	.389*	0.06	1.00
7 Elaborations	0.08	0.28	0.11	0.02	-0.09	.370*

Table A2. The correlations in open prompt + self-explaining preference condition

	1.00	2.00	3.00	4.00	5.00	6.00
1 Prior knowledge performance	1.00					
2 Learning performance	0.26	1.00				
3 Cognitive load	-0.27	-0.15	1.00			
4 Percentage of dwell time on prompt	-0.01	-0.01	-0.01	1.00		
5 Percentage of dwell time on content	0.08	-0.19	0.08	0.28	1.00	
6 Concepts	-0.13	0.30	-0.13	.467**	-0.23	1.00
7 Elaborations	.401*	.433*	0.26	-0.04	0.10	0.13

Table A3. The correlations in focused prompt + no self-explaining preference condition

	1.00	2.00	3.00	4.00	5.00	6.00
1 Prior knowledge performance	1.00					
2 Learning performance	-0.04	1.00				
3 Cognitive load	0.04	-0.09	1.00			
4 Percentage of dwell time on prompt	-0.01	-0.33	0.08	1.00		
5 Percentage of dwell time on content	0.33	0.30	0.15	-0.26	1.00	
6 Concepts	0.21	-0.09	0.04	.409*	-0.33	1.00
7 Elaborations	-0.05	.549**	-0.09	0.01	-0.02	.383*

Table A4. The Correlations in Open Prompt + No Self-Explaining Preference Condition

	1.00	2.00	3.00	4.00	5.00	6.00
1 Prior knowledge performance	1.00					
2 Learning performance	.471**	1.00				
3 Cognitive load	-0.08	0.07	1.00			
4 Percentage of dwell time on prompt	-0.06	-0.04	0.09	1.00		
5 Percentage of dwell time on content	0.28	0.29	0.28	-0.07	1.00	
6 Concepts	-0.10	0.21	-0.17	0.35	-0.27	1.00
7 Elaborations	-0.20	0.14	0.02	0.06	-0.04	.532**

An innovation-based virtual flipped learning system in a ubiquitous learning environment the 21st century skills of higher education learners

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ABSTRACT: This research aims to develop an innovation-based virtual flipped learning system in a ubiquitous learning environment to enhance twenty-first-century learning skills in information, media, and technology of learners in higher education. The study employed a design-based research method to study the needs and user experiences of students and teachers. The system consists of three components: (1) a flipped classroom, (2) a virtual learning system and (3) a ubiquitous learning environment and involved five steps: (1) preparing learners, (2) setting learning objectives, (3) self-studying online content, (4) meeting with teachers and classmates to expand knowledge and (5) assessing results. The participants were 97 undergraduate students. This study found that students had twenty-first-century learning skills in information, media, and technology literacies after studying were significantly higher at the highest level in every skill. The average scores of the test before the study, during the study and after the study had heightened attitude levels and information, media, and technology literacies with statistical significance at the .05 level. The results of the test after the study had the highest average scores, followed by those from and before the study. This indicates that the developed innovation can improve the overall attitude and information, media, and technology literacies of learners.

Keywords: Virtual learning, Flipped learning, Ubiquitous learning environment, 21st century skills, Higher education

1. Introduction

Essential skills for working in the twenty-first century include critical thinking, leadership, and those media and technology skills that will help workers adapt to global changes, especially in the immediate context of the COVID-19 pandemic (World Economic Forum, 2020). In addition, the Education 2030 Framework for Action discusses the use of information technology in teaching and learning that, in turn, promotes lifelong learning. It focuses on flexibility in learning to create opportunities for informal learning, enhance classroom learning and support skills acquisition in media, information and technology (UNESCO, 2015). This is in line with Thailand's current strategies to move the country toward Thailand 4.0, focusing on driving the economy through innovation. (The Secretariat of the Prime Minister, 2017) Therefore, the development of education must be in line with the provision of manpower that meets the needs of the country. To develop highly qualified learners with a high standard according to the objectives, educational technology has played an important role in driving the quality of learning to meet the needs of the global society including Thailand (National Education Act, 2010).

This is consistent with the policy statement of Thailand's Ministry of Information and Communication Technology (2014), which proposed policies related to the application of information and communication technology to enhance lifelong learning (e.g., smart learning). The report promoted innovation in teaching and learning by applying information technology to reform teaching styles and processes for learning at all levels. Mobile electronic devices have been used to enable students to learn anywhere and anytime. In addition, according to the Global Digital Use Survey in 2021, Thailand has 97.7% of internet usage through mobile devices and a 7.4 % increase in the usage trend (Kemp, 2021).

Learners in the digital age expect more interactive and challenging technology than that found in traditional classroom teaching settings that mostly offers lectures and discussions. Therefore, teachers should recognize the value of adding new, alternative learning methods for organizing learning, which means that learners will learn effectively. The teachers should focus on providing learners with lifelong learning skills and the learning skills necessary for the twenty-first century, including thinking skills and meaningful learning through information technology. This will lead to the ultimate goal of education, which is to create innovations, resulting in learners

becoming valuable citizens in a global society (Haryani et al., 2021; Khlaisang & Mingsiritham, 2016; Portuguez Castro & Gómez Zermelo, 2020; Yusuf et al., 2021).

To address the above issues concerning information, media, and technology literacies literacy in the 21st century learning, life-long learning with all-time access to learning resources, and responses to the demands of the ever changing global society, especially in terms of the use of technology in learning as a result of the COVID-19 pandemic, a virtual flipped learning system is employed. The system allows students and teachers to interact and learn together. It also emphasizes the learning process on a conditional basis and in real-world contexts through various mobile devices that students already have, based on the Bring Your Own Devices concept. The design is based on the ubiquitous learning environment (ULE). Learning can happen anywhere and anytime, allowing students to learn by themselves. However, teaching experience and age can affect undergraduate students' professional development and digital competence. Therefore, regarding education policy, enhanced digital competence would enable students to act in to act as empowered citizens concerning responsible technology use (Inamorato dos Santos et al., 2023).

The concept focuses on knowledge-building so that students can learn meaningfully. It allows learners to access information as needed. Students can communicate and interact with teachers and classmates to exchange information and discuss the learning process and content (Feng & Hu, 2020; Khlaisang, 2018; Mohaimen-Bin-Noor et al., 2021; Pishtari et al., 2020; Suartama et al., 2021). Flipped classrooms appear to contribute to cognitive and social constructivism by exchanging opinions among learners (Dalbani et al., 2022).

In addition, the virtual flipped learning system answers the needs of twenty-first-century learning skills for information, media, and information and communication literacy. It expands learning time and develops digital literacy without limitations of time and place. Therefore, it can be seen that the application of technology that students are already familiar with, including the use of the learning system, the use of mobile devices combined with flipped learning and virtual learning, can create a teaching innovation that meets the needs of digital literacy of learners in the twenty-first century. This aligns with the study by Cekić-Jovanović et al. (2019) on the impacts of the flipped classroom on improving the future competencies of undergraduate students in the Faculty of Education. It was found that the flipped classroom positive impacted learners' socio-emotional skills, ICT literacy, and learning to learn. In addition, Latorre-Coscolluel et al. (2021) suggested that flipped classrooms could enhance learners' future skills, including collaboration, communication, and citizenship.

However, some studies have addressed the limitations of virtual flipped learning, including the issue of students' lack of preparation (Shyr & Chen, 2017) and a lack of interest in the media presented (Pugsee, 2017). Mobile devices were used to address these problems. This supports the ULE that reduces the limitations of the virtual learning environment in terms of expensive and hard-to-access virtual reality technologies (Zhang et al., 2018). The devices can support interoperability between physical and virtual environments and promote learning in an online and real-time environment made up of different types of learning and support collaborative learning (Virtanen et al., 2016).

This study aims to develop an innovation-based virtual flipped learning system in the ULE to enhance twenty-first-century learning skills in information, media, and technology of higher education learners. This research design is based on the cognitive and social constructivism learning theory through self-directed learning, knowledge sharing, and constructionism to enhance learners' ICT literacy and soft skills. In addition to developing learners' information technology literacy, it promotes personalized learning in response to personalized individual learning and physical limitations using a chatbot. The study followed the design-based research (DBR) model based on the theory of design principles from the user experience (UX) and learning theories. It studied the results of the use of learners' innovation to obtain guidelines for further application. For example, the study of Julie et al. (2020) used design-based research to design learning activities and the use of technology by exploring the opinions of students, teachers, activity designers, and experts in media and computer science in order to enhance learners' digital literacy. Another study by Sekarningsih et al. (2021) adopted design-based research of which its elements including design, development, evaluation, and revision, in designing web-based learning to support teaching and learning management during the COVID-19 pandemic

2. Literature review

2.1. Educational 2030 framework

The Sustainable development is the goal of UN Education in 2030, of which the emphasize is on high quality and equitable education and life-long learning. For this study, the key objectives are as follows: (1) an increasing number of learners possess the skills required in the workplace and labor market as well as entrepreneurship, (2) people in general have the opportunity to develop different types of literacies, and (3) every learner has the knowledge and skills required for sustainable self and peer development and for becoming a competent global citizen (UNESCO, 2015).

2.2. Flipped classroom

A flipped classroom is a learning management process that uses technology to facilitate learning. This emphasizes the use of video streaming to deliver learning content before teaching and learning activities. Classroom activities aim to expand knowledge through the use of various technologies suitable for interactive learning, and the flipped classroom employs various mobile devices to allow students to create projects, assignments, and innovations (Beason-Abmayr et al., 2021; Kang & Kim, 2021; Madariaga et al., 2021; Velde et al., 2021). Studies showed that flipped classrooms helped individuals to learn the contents at their own pace, promoted learning through technology both inside and outside the classroom and enhanced the 21st-century skills, high-order thinking skills, and soft skills (Khlaisang, 2018; Khlaisang et al., 2021; Ferguson, 2023). In addition, flipped learning combines forms of synchronous and asynchronous learning that foster constructivist learning (Fuchs, 2021; Noguera et al., 2022). Steps in organizing flipped classroom learning activities are : (1) preparing learners and the environment, (2) setting learning strategies and objectives, (3) selecting the appropriate technology to transfer the content to enable learners to develop conceptualization and learning, (4) organizing activities to motivate learners to advance their learning at a high level and to ensure that learners have access to the technology required for learning, and (5) using various assessment methods (Bergmann & Sams, 2012; Hamdan et al., 2013; Khlaisang, 2018; Wang, 2021).

2.3. Virtual learning system

The virtual learning system is the structure of teaching through an IT system including computers, laptops, mobile devices, and applications in the same manner as found in normal teaching. It has the features of classroom participation, learning content, tests, homework, grading, assessments, and other external resources to facilitate learning. Students and teachers can communicate and discuss issues at any time. Learners can study content anytime, anywhere, with various devices. There are interactive and collaborative modes of teaching. It is regarded as the management of distance education in a borderless world where there are no restrictions on time, place, or access to equipment (Martín et al., 2021; Phelps & Vlachopoulos, 2020; Rashid et al., 2021; Zhao et al., 2010). Rosmansyah and Ashaury (2018) used a 3D virtual environment to develop learners' 21st century learning skills. It was found that the virtual environment helped improve learners' self-directed learning skills, ICT literacy, problem-solving skills, and thinking skills. The key components of an effective learning system are: (1) addressing content management and presentation, (2) providing teaching materials and learning activities, (3) employing both synchronous and asynchronous communication, (4) interaction, (5) a learner tracking system, and (6) facilitating tools for learners (Ducange et al., 2017; Weller, 2007).

2.4. Ubiquitous Learning Environment (ULE)

The ULE is a learning environment where learners can learn anywhere and anytime via wireless devices and learners can learn and work together. An assessment is conducted according to the actual conditions. Instant feedback is provided to enable learners to improve their learning (Ahmed et al., 2017; Liu et al., 2021; Qun, 2021). The important components of ULE are : (1) allowing learners to study anytime and anywhere, (2) an emphasis on self-studying and knowledge-building to enable learners to learn meaningfully, (3) using computer systems in learning management and data management, (4) using a wireless network connection, (5) allowing learners to access information as needed, (6) enabling communication and interaction between teachers and learners to exchange information and discuss issues, and (7) taking into account the learning environment, both the real environment and virtual environment, which can be adapted from the use of technology to detect the learner's position, as well as to provide sufficient information for learners. Vladova et al. (2019) used a chatbot

as an avatar in the online learning of individual learners to assist learners and provide them with flexibility in learning. Similarly, Neumann et al. (2021) used a chatbot as a tool to check the learners' learning process in order to promote self-directed learning among university students. Therefore, a chatbot was used in this study as a tool to answer students' problems. Its prominent feature is flexible communication. It facilitates communication anywhere, anytime through a variety of communication channels (Mobility), interaction (Interactivity), and meeting individual learning needs (Personalisation). It provides convenient communication to learners and responds to learning. The chatbot used in this study is in the form of a retrieval-based model that was developed by setting conditions and having a set of instructions and pre-defined dialogues to communicate with learners (Cárdenas-Robledo & Peña-Ayala, 2018; Chin & Chen, 2013; Huang & Chiu, 2015).

2.5. Twenty-first-century learning skills in information, media, and technology

OECD (2008) stated that the 21st century learning skills were important to the global economy. The three main skills were (1) life and career skills, (2) learning and innovation skills, and (3) information, media, and technology skills. This research applies those twenty-first-century learning skills that comprise three key fundamental components: (1) information literacy, (2) media literacy, and (3) ICT literacy. Other soft skills, such as communication skills, collaboration skills, and attitude, were also used to achieve learning. According to Khlaisang and Koraneekij (2019), information literacy referred to the level of knowledge and understanding of the appropriate and effective use of information. Media literacy referred to the ability to access, analyse, evaluate, and create information in different contexts as well as realize the impacts of media exposure and the ability to select useful information and suppress inappropriate information. ICT literacy referred to the ability to use digital technology, communication tools, and/or networks to access, manage, integrate, evaluation, and create a digital media in a knowledge society.

3. Methodology

3.1. Participants

The participants in this study were 97 higher education students, including 63 females, accounting for 64.9% and 34 males, accounting for 35.1% of the cohort. Simple random sampling was used to recruit samples representing the population of undergraduate students in the Faculty of Education with similar ability levels. They were classified into two groups according to their fields of study, including general disciplines and computer-related disciplines. As this was a trial of educational innovation, the emphasis was placed on one experimental group, and no control group was used. The largest group of participants (34 students) were 21 years old, accounting for 35.1%, followed by 20 years old (27 students, accounting for 27.8%) and 22 years old (24 students, accounting for 24.7%). The 58 students who studied general disciplines accounted for 59.8% and 39 students who studied computer and educational technology, accounting for 40.2%. Most participants (64 students) were in their third and fourth year of study, accounting for 66.0%, and 33 students were in their first and second year of study, accounting for 34.0%.

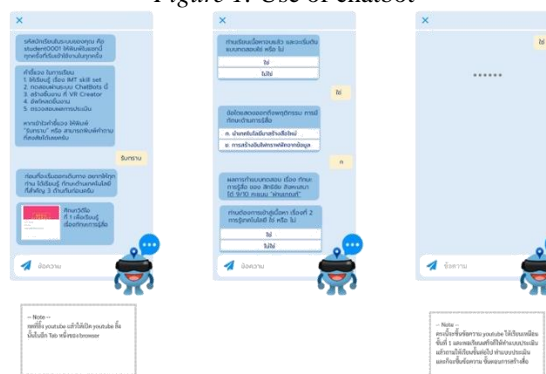
In terms of computer ownership, almost all students (96 students) had their own computer, accounting for 99.0%. Most students (66 students) had used technology to develop a virtual learning environment, accounting for 68.0%. Most of them used the Thinglink program for virtual learning and 31 students, 32.0% had never used virtual learning. In addition, when considering the chatbot experience, 85 students, 87.6%, used the Line application, followed by Facebook. Similarly, 81 students, 83.5%, had used the flipped classroom. Students used video streaming/on-demand applications most, followed by Massive Open Online Courses (MOOCs) and e-learning. Most students (44 students) self-reported that they have had a high level of confidence, accounting for 45.4%, followed by a moderate level of confidence, 34 students, 35.1%, and a low level of confidence 19 students, 19.6%.

3.2. Experimental design

This study is an exercise in the research and development of learning innovations. The study used the DBR approach to collect information about the UX to act as data in the design along with design principles and learning theories. This research employed multimedia principles (Clark & Mayer, 2011) such as the contiguity principle, personalization, voice and image principle. It applied a chatbot as a learning assistant for learners (Figure 1). learning was conducted through video media. The content was divided into presentations following

the segmenting and pertaining principles. In addition, the learning theory of cognitive constructivism and social constructivism have been applied for activity design that allowed learners to reflect after learning.

Figure 1. Use of chatbot



3.3. Research innovation

This design-based research resulted in an innovation called VR Journey, a platform where learners independently learned about information literacy, media literacy, and technological literacy using a chatbot (Figure 1). This flipped learning was based on cognitive constructivism. Subsequently, the learners undertook their works in the VR Creator (Figure 2) with an emphasis on enabling learners to apply their knowledge through creations, and they later exchanged ideas with their peers in the VR Gallery (Figure 3). This flipped learning was based on social constructivism. In this process, learners were able to develop their soft skills (collaboration and communication).

VR Journey was a web application designed and developed by the researchers. Learners entered the learning system at <https://vrjourney.club/>. While participating in the activities, learners learned the content independently with the help of a chatbot on Facebook Messenger, which was available at all times. Learners also received feedback on the completed activities from the teacher (Figure 1). Before the course began, learners had to take a pre-test to assess their knowledge. Learners then learned the content about twenty-first-century learning skills in information, media, and technology on YouTube. After each topic was delivered, learners had to use the knowledge obtained from the course to create a piece of media in the form of virtual reality using Thinglink on VR Creator (Figure 2). Learners could add hashtags, like others' work, and share their work on VR Gallery (Figure 3).

Figure 2. VR creator

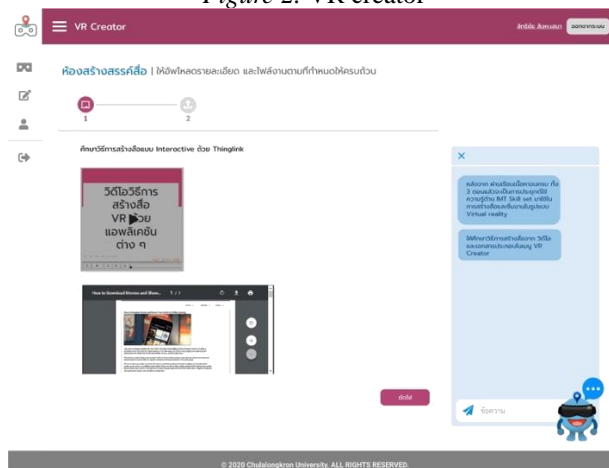
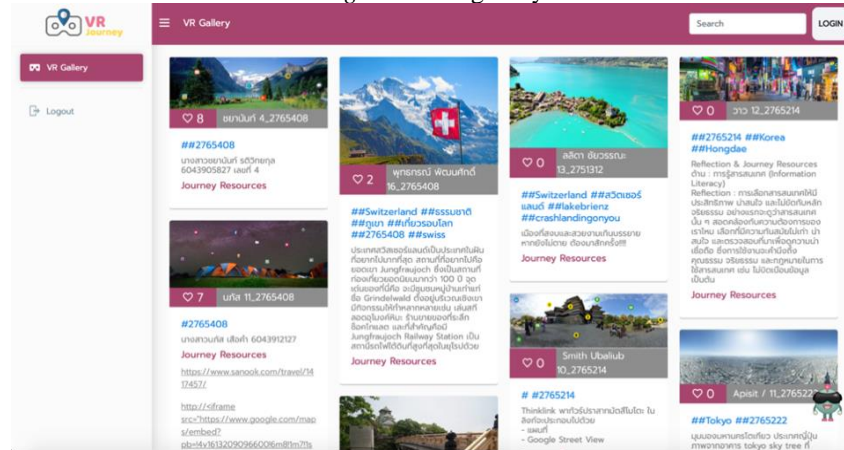


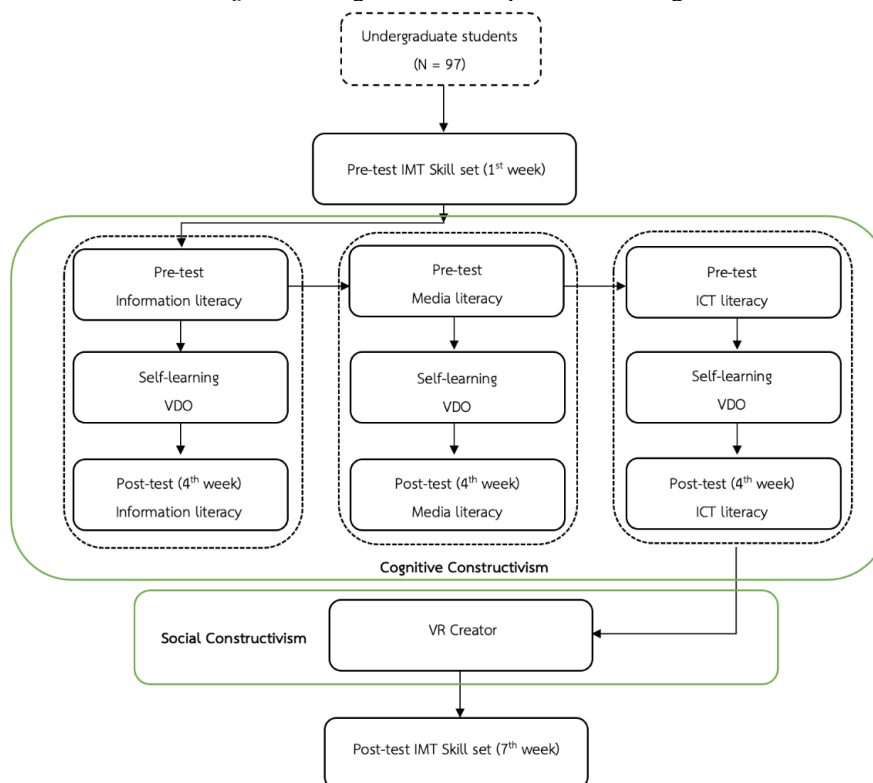
Figure 3. VR gallery



3.4. Experimental procedure

Figure 4 shows the steps in the experiment. Students registered via a chatbot at <https://vrjourney.club> and took a pre-test. The content was presented sequentially starting from information literacy, media literacy, to technological literacy. When the students had finished studying, they reflected on what they had learned and applied that knowledge to create an authentic project using the VR Creator with assistance from a chatbot and presented their work in the VR Gallery.

Figure 4. Diagram of the experimental design



3.5. Instrument

3.5.1. Model of an innovation-based virtual flipped learning system

A model of an innovation-based virtual flipped learning system in a ULE to enhance twenty-first-century learning skills in information, media and technology of higher education learners has three components: (1) the

Flipped Classroom, (2) a virtual learning environment and (3) an ULE and involved five steps: (1) preparing learners, (2) setting learning objectives, (3) self-studying online content, (4) meeting with teachers and classmates to expand knowledge, and (5) assessing the actual conditions, as shown in Figure 5 and Table 2. The evaluation results regarding innovation types and descriptions were verified by nine experts, and the learning model was found to be feasible ($M = 4.78$, $SD = 0.42$).

In this study, exploratory factor analysis was conducted to assess fundamental components of learning innovation design and development. The analysis results revealed four components (Eigen value = 1.681, Cumulative = 71.321), namely (1) the characteristics of the virtual flipped classroom, (2) the characteristics of ubiquitous learning environment, (3) the learning management to promote twenty-first-century learning skills in information, media, and technology, and (4) the learner roles, as shown in Table 1. There were also learning steps in line with these components to improve twenty-first-century learning skills in information, media, and technology of undergraduate students, as shown in Table 2.

Figure 5. Model of an innovation-based virtual flipped learning system

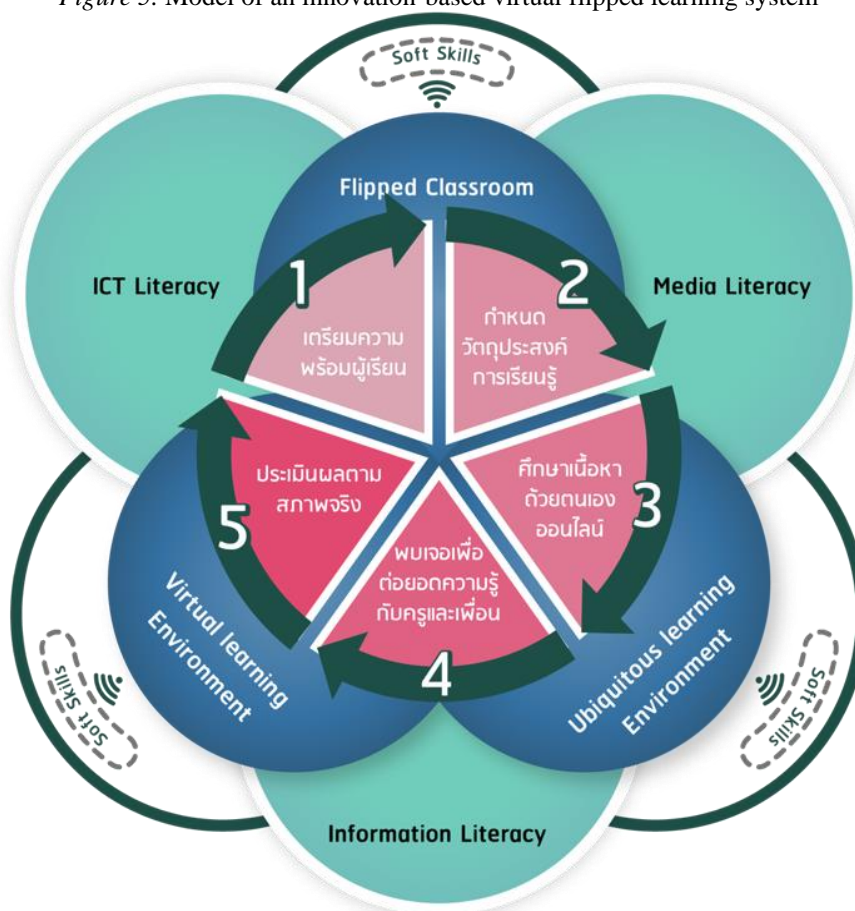


Table 1. Factors and meaning

Factors	Meaning
1. Characteristics of the virtual flipped classroom	The virtual flipped classroom refers to the instruction delivered online through a computer or an online device. It is similar to a traditional classroom in that there are attendance, structured content, testing, knowledge accumulation, and assessment and evaluation. It allows flexibility in learning as learners can learn the content anywhere, anytime, while interacting with one another. With the assistance of a chatbot, learners can learn and work collaboratively.
2. Characteristics of ubiquitous learning environment	A ubiquitous learning environment is the learning context that considers learners' learning environment. Learners can learn anywhere, anytime, as it highlights self-directed learning, constructivism, and meaningful learning. In this study, a chatbot is used as a tool to facilitate these purposes. The dominant features of ubiquitous learning are its communication flexibility, communication channel mobility, interaction, and personalization. It allows learners to communicate conveniently and learn effectively.

3. Learning management to promote twenty-first-century learning skills in information, media, and technology	This learning management uses technology to facilitate learning-based video streaming for delivering content about twenty-first-century learning skills in information, media, and technology. Learners later use the knowledge obtained from the course and technology to create a piece of media in the form of virtual reality.
4. Learner roles	Learner roles include the ability to access learning resources, the ability to use technology for learning, and the ability to manage time for learning.

Table 2. Learning steps

Steps	Details
1. Preparing learners (Factor1 and 2)	At this stage, students log in to the system by using the code received from teachers and learn about course details through Bot Greeting.
2. Setting learning objectives (Factor 1)	At this stage, students will be given instructions on how to execute activities the chatbot.
3. Self-studying online content (Factor 3 and 4)	Students acquire twenty-first-century learning skills in information, media, and technology through video streaming, facilitated by chatbots. When students finish studying the video, they will take a test via a chatbot to assess their learning. If the students do not pass the test, the system will let them study again and take the test again. If students pass the test, the system will show the next item of content to study.
4. Meeting with teachers and classmates to expand knowledge (Factor 3 and 4)	Once the students have completed learning modules, the chatbot will direct them to the VR Creator room. Students will apply their information, media, and technology skills to create virtual reality media and projects. Students learn how to create interactive media via Thinglink and choose the tools to create work according to their interests.
5. Assessing the results. (Factor 4)	Students present their work in the VR Gallery. Viewers can wear a device to view or choose a normal view. In addition, on the student's profile page, they can check their learning progress, including scores and feedback from teachers.

3.5.2 Data collection

The tools used to obtain quantitative data in this study were (1) a questionnaire on learning skills and attitudes consisting of 10 situational questions with a 5-point rating scale; (2) assessment forms for information literacy, media literacy, and technology literacy categorized by learning topics with a 5-level rating scale; and (3) a rubric for evaluating students' work. Before being used for data collection, the tools were validated by five experts in educational technology and assessment and evaluation. In the internal consistency analysis, Cronbach's alpha coefficient was .887.

The qualitative data were collected through observation during the working period using scoring rubrics for 21st century skills in information, media, and technology literacy, and soft skills, such as collaboration and communication, in addition to interviews of learners.

3.5.3 Data analysis

Two-way analysis by MANCOVA repeated measurement was conducted to compare the differences in twenty-first-century learning skills in information, media and technology literacy before, during and after the study by self-learning in a ULE and using smart, wearable technology devices, classified by the field of study and the year of study, with experience in using computers as an extraneous variable. Performance assessment was conducted by using rubrics scoring. Information, media, and ICT literacy before and after the study were assessed by using dependent *t*-test analysis.

4. Result

4.1. Analysis results of twenty-first-century learning skills in information, media and technology

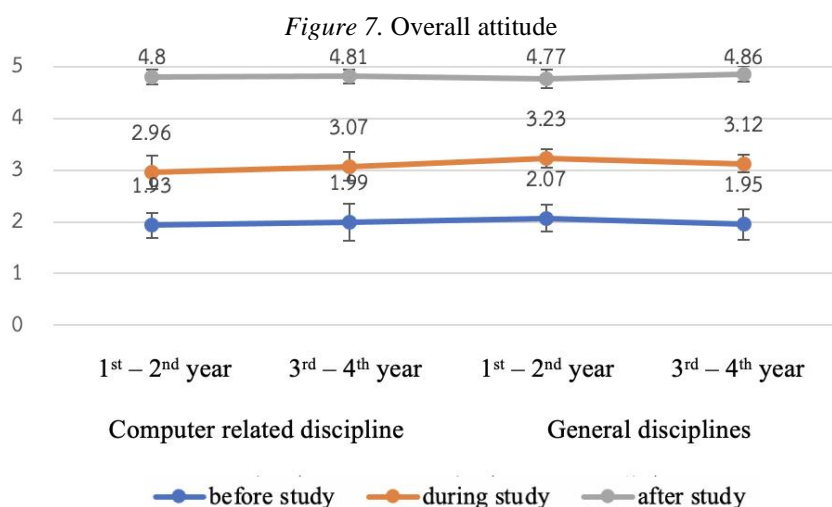
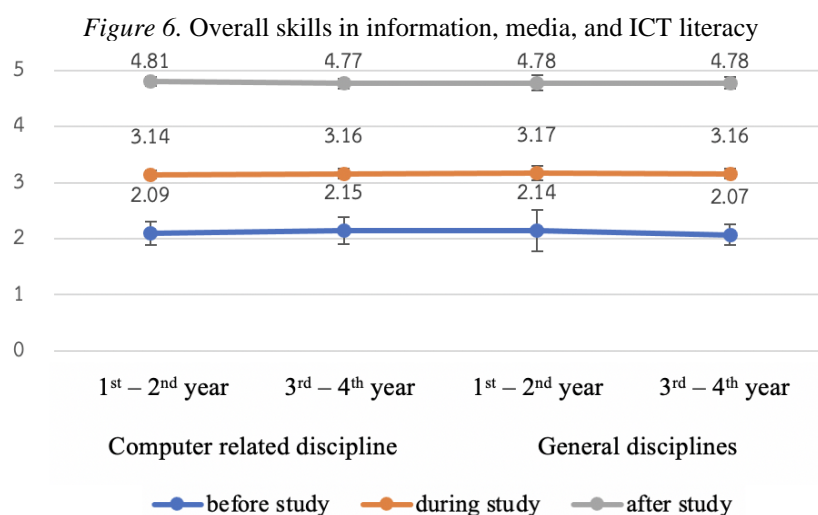
Table 3 presents the results of the analysis of twenty-first-century learning skills in information, media and technology by comparing the results before, during and after learning. During and after learning, it was found

that learners have all twenty-first-century learning skills in information, media, and technology at the highest level. It can be seen that the innovation-based virtual flipped learning system in a ULE helped students to develop skills in information, media, and technology.

When classified by the field of study and year of study, with experience in using computers as an extraneous variable, it was found that the variables of the field of study and year of study did not affect the attitude and information, media, and technology literacy with statistical significance at the .05 level ($F = 1.898, 1.179$; $sig = .153, .310$). However, when considering the assessment, it was found that the average scores of before, during, and after study assessments, students had a different level of overall attitude and information, media and technology literacy with statistical significance at the .05 level ($F = 79.438, 156.455$; $sig = .000, .000$). The average scores after the study were the highest. Details are shown in Figures 6 and 7.

Table 3. Skills in information, media, and technology literacy

21st-century learning skills	Assessment								
	Before study			During the study			After study		
	<i>M</i>	<i>SD</i>	Level	<i>M</i>	<i>SD</i>	Level	<i>M</i>	<i>SD</i>	Level
1. Attitude	1.98	0.30	Low	3.10	0.24	Medium	4.82	0.15	Highest
2. Skills in information, media and technology									
2.1 Information literacy	1.94	0.30	Low	3.12	0.07	Medium	4.91	0.06	Highest
2.2 Media literacy	2.11	0.38	Low	3.22	0.15	Medium	4.57	0.17	Highest
2.3 Technology literacy	2.26	0.35	Low	3.13	0.23	Medium	4.87	0.23	Highest
Overall	2.10	0.24	Low	3.16	0.10	Medium	4.78	0.10	Highest



4.2. Analysis of the results of opinion analysis on skills in information, media, and ICT

Data analysis results on the opinions about information, media, and technology literacy before, during and after study found that the students had the highest level of opinions and behaviors on information, media, and ICT literacy after the study, as shown in Table 4.

Table 4. Level of opinions and behaviors on information, media, and technology literacy

Information, media, and Technology literacy	Full score	Assessment					
		Before study		During the study		After study	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Level of opinions	5	2.33	0.25	3.68	0.25	4.83	0.13
Level of behaviors	10	8.54	1.00	9.43	0.72	9.81	0.49

Table 5. The level of opinions and behaviors on information, media, and ICT literacy, classified by the field of study and year of study

Information, media, and technology literacy	Field of study	Year of study	Full score	Assessment					
				Before study		During the study		After study	
				<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Level of opinions	Computer-related discipline	1–2	5	2.34	0.19	3.63	0.33	4.86	0.08
		3–4	5	2.30	0.28	3.71	0.18	4.79	0.13
	General disciplines	1–2	5	2.38	0.20	3.68	0.23	4.82	0.16
		3–4	5	2.33	0.28	3.69	0.26	4.84	0.14
Level of behaviors	Computer-related discipline	1–2	10	8.56	0.81	9.37	0.72	9.94	0.25
		3–4	10	8.57	1.20	9.52	0.79	9.65	0.71
	General disciplines	1–2	10	8.47	1.01	9.24	0.56	9.71	0.47
		3–4	10	8.54	0.98	9.49	0.75	9.90	0.37

Figure 8. Level of opinions on information, media, and ICT literacy

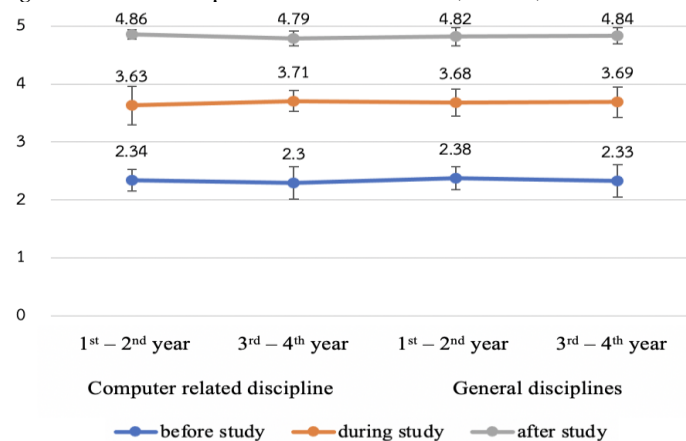
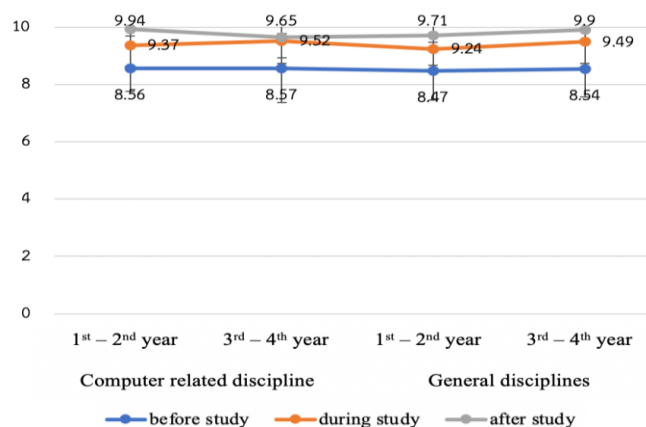


Figure 9. Level of behaviors on information, media, and ICT literacy



When classified by the field of study and year of study, with experience in using computers as an extraneous variable, it was found that variables of a field of study and year did not affect the level of opinions and behaviors on information, media, and technology literacy with statistical significance at the .05 level ($F = .780, .793$; $sig = .460, .454$). However, the assessment found that students had a different level of opinions and behaviors on information, media, and technology literacy before, during, and after the study with statistical significance at the .05 level ($F = 193.305, 4.189$; $sig = .000, .000$). The opinions and behaviors on information, media, and technology literacy after the study had the highest level, as shown in Table 5. Details are shown in Figures 8 and 9.

4.3. Analysis of results of performance assessment in information, media, and technology literacy using the rubrics assessment criteria

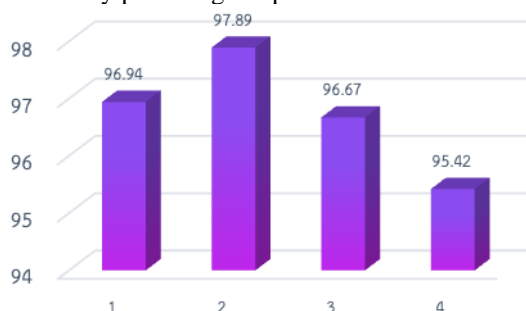
Performance assessment by teachers using the rubrics assessment criteria in information, media, and ICT literacy found that students had overall scores at a good level ($M = 90.16, SD = 2.10$). When assessing each item, it was found that students had average scores in information literacy, media literacy, and technology literacy and social skills at a good level in every skill ($M = 29.08, 23.49, 29.00, 8.59$; $SD = 0.83, 0.58, 1.22, 0.52$), as shown in Figure 10. Sample work and written reflections are shown in Figure 11.

In addition, there was an assessment of information, media, and ICT literacy by using pre-test and post-test. The results of the data analysis revealed that students had higher average scores after the study with statistical significance at the .05 level ($t = 26.447, sig = .000$), as shown in Table 6.

Table 6. Analysis results of differences in average scores before and after study

Assessment	Full score	<i>M</i>	<i>SD</i>	<i>t</i> -test	<i>sig</i>	Result
Before study	10	6.16	0.95	26.447	.000	After > Before
After study	10	9.32	0.74			

Figure 10. Literacy percentage of performance assessment score level



Note. 1 = Information literacy, 2 = Media literacy, 3 = ICT literacy, 4 = soft skills

Some answers from the interviews of VR Journal users:

“Using flipped classroom learning theory with self-directed learning via lecture videos effectively promotes flexibility in learning as learners can learn anywhere, anytime, and as many times as they need.”

An undergraduate student in a non-educational technology-related major

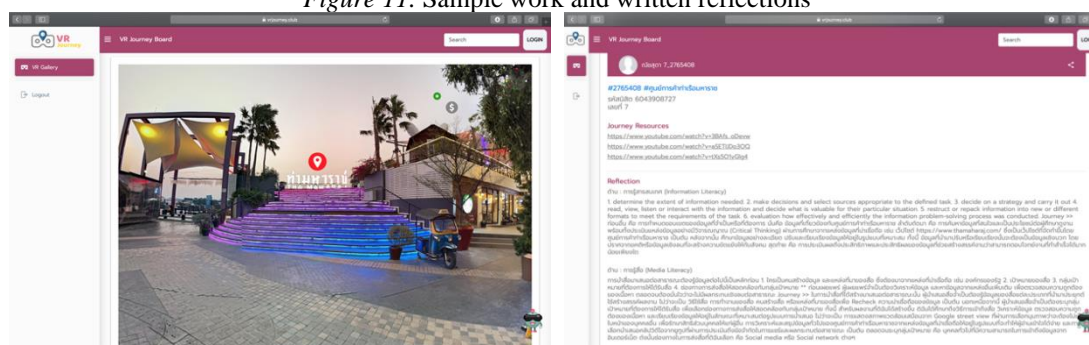
“During the COVID-19 pandemic, I realized the significant role of technology in online learning. Also, it is essential to design learning activities that promote learner engagement, resulting in learners’ motivation and discipline.”

An undergraduate student in a non-educational technology-related major

“Creating interactions between learners and teachers through learning activities and conducting cumulative learning activities, such as keeping reflective learning logs of what they have learned and how they can expand it, can create active learning, knowledge retention, and, finally, actual construction of knowledge.”

An undergraduate student in an educational technology-related major

Figure 11. Sample work and written reflections



5. Discussion

The analysis of twenty-first-century learning skills in information, media and ICT literacy revealed that students had twenty-first-century learning skills in information, media and ICT literacy after study in every skill at the highest level. The innovation-based virtual flipped learning system allowed students to study the content on their own by watching streaming videos which the students prepared before class. A chatbot was used as a learning assistant. It presented learning steps and helped students to access learning resources conveniently. Students can receive feedback from activities through a chatbot. Therefore, students who had limited computer experience could easily learn and carry out activities. This is consistent with the research by Mckie and Narayan (2019) that used chatbots to create learning experiences for learners. The study found that the use of chatbots in higher education was convenient and made students feel confident to use them. In addition, the use of chatbots also allowed students to monitor their own learning progress and access learning content easily (Smutny & Schreiberova, 2020; Kuhail et al., 2023). This study also investigated the background of students from different majors, divided into two groups: (1) computer-related disciplines and (2) general disciplines. The findings revealed that teachers, instructional designers, and researchers could use this innovation with students of all majors, including IT-related majors and others, to develop students' skills in information literacy, media, and technology. Teachers could make practical use of this innovation in their subjects by allowing students to study the content on their own or using it as part of the lessons. As this technology was flexible and learning resources and activities were easy to access, using this technology with chatbots would enable students to learn anywhere, anytime, responding to the personal learning styles of students (Kaiss et al., 2023). In addition, this study looked further into the details of skills in three areas: information literacy, media literacy, and information and communication technology literacy are as follows.

Information literacy. Students in the later years of study had higher information literacy. When considering the variable in the field of study, students who studied in general disciplines had higher average scores than those who studied in a computer-related discipline. This reflects the fact that this developed innovation can be applied to general students and need not be limited to students in the field of a computer-related discipline. After having completed self-study through video streaming, students conducted self-assessment and reflection of information literacy and additional resources they had consulted. This is consistent with research by Gómez-García et al. (2020), reviewing the literature on how to apply flipped classroom learning to improve information literacy. The results of the study revealed that the design of activities focused on the students' participation in learning and self-control in learning. The system allowed students to learn by watching videos and animation media. Learning in modules can improve information literacy.

Media literacy. Learning innovations encouraged students to reflect and search for more information and create work using Thinglink. This is in line with research by Rajagopal et al. (2020) that designed learning in a virtual learning environment that allowed students to carry out activities together. The results showed that a virtual learning environment can promote learners' media literacy.

Information, Communication and Technology literacy. Data analysis showed that students had the highest information technology and communication literacy after the study. An innovation-based virtual flipped learning system-developed information technology and communication literacy by allowing students to reflect and search for additional information and create works using Thinglink. This is the application of knowledge gained from learning to create work in a virtual format. It is in line with Torres-Madroño et al. (2020), which discussed the use of digital tools, virtual tools, and reflective activity design to develop students' information technology and communication literacy.

Attitude. Data analysis found that students had better learning attitudes after the study than during and before the study. It showed that the innovation-based virtual flipped learning system could motivate learning through participation in activities and self-direct learning by searching for information and creating works according to one's interest. The design employed various virtual tools, including the use of chatbots to help students learn (Alnasib & Ali, 2020; Morris & McDermott, 2022; Smutny & Schreiberova, 2020).

6. Conclusion

The research on an innovation-based virtual flipped learning system in a ULE to enhance twenty-first-century learning skills in information, media, and technology of higher education learners used DBR. The researcher collected information on the user UX to be initial data in the design together with design principles and learning theories. The research results found that the innovation can enhance twenty-first-century learning skills in information, media and technology literacy and improve learners' attitudes. This innovation can be used with learners in various contexts, such as learners with experience in using technology and those studying in different fields. The innovation can be integrated into classroom activities and used as additional learning resources to help learners develop their twenty-first-century learning skills in information, media, and technology literacy wherever and whenever they wish. The system can be applied to students in all disciplines to develop information, media, and technology literacy. Teachers can apply this innovation in their courses by having students study the content on their own. It can also be used as a part of teaching and learning management in the course. This innovation offers flexible learning and allows convenient access to learning resources and activities. Students can learn anywhere and anytime with the use of chatbots that meet their individual learning needs.

However, the results of the data analysis revealed that when considering the field of study and year of study, with experience in using computers as an extraneous variable, students' information, media, and technology literacy did not affect their attitudes and information, media and technology literacy. Therefore, a future study may look at other extraneous variables such as the learning success rate and learning behaviors to gain more insight into the learner's user experience, leading to the development of innovation for optimal efficiency.

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Authors' contributions

JK and TT conceived and designed the experiments, and JK performed the experiments. JK and TT analyzed and interpreted the data. JK and TT contributed reagents, materials, analysis tools, or data; and JK and TT wrote the paper. All authors have read and approved the final manuscript.

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Declarations

Ethical considerations

In this study, the researchers have obtained consent from the participants to give their responses. The informed consent forms were distributed to the teachers involved in our survey, and the signed privacy consent forms were collected. The researchers ensured the anonymity of the participants as well as their freedom to withdraw from

the study at any time with no need to give reasons. The data were kept during the study and destroyed upon completion of the study. Only researchers had access to the data.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors have no competing interests.

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The effect of video lecture types on the computational problem-solving performances of students

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ABSTRACT: This study investigated the effect of video lecture types on the performance of students in computational problem-solving practices. A total of 19 university students participated in the computational problem-solving practices that mostly required declarative knowledge, and 22 university students participated in the computational problem-solving practices that mostly required procedural knowledge. The practices were implemented in the Algorithm and Programming course and the Computer Programming II course. Three video lecture types (instructor-whiteboard, instructor voice-handbook, instructor-slides) were used in both courses. The one-way repeated measures ANOVA test was employed to determine if there was a significant difference between the problem-solving performances of the students based on the video lecture type. In the Algorithm and Programming course that required mostly declarative knowledge, the problem-solving scores of the students were significantly higher after the instructor voice-handbook video practice than those after the instructor-whiteboard video practice. On the other hand, in the Computer Programming II course that required mostly procedural knowledge, the problem-solving scores of the students were significantly higher after the instructor-whiteboard video practice than those after the instructor voice-handbook video practice. The students showed higher performance in the video lecture types they preferred in both courses. The students listed the factors that affect their video preferences as (a) the effect of the presence of an instructor in the video lecture on their attention, (b) the efficiency of the video lecture in examining many and various examples in a limited time, (c) the opportunity provided by the video lecture to revise the content and procedure, and (d) the efficient presentation of the knowledge. It is recommended that an instructor should be present in the video that includes mostly procedural knowledge, while there is no need for an instructor in the video that includes mostly declarative knowledge regarding computational problem-solving activities.

Keywords: Computational thinking, Video lecture, 21st century skills, Online learning

1. Introduction

Computational thinking (CT) is an approach to problem-solving that requires the use of core computer science concepts and logic skills to transform a problem into a more easily understandable form and design a system that can be comprehended by others (Qualls & Sherrell, 2010). CT is a skill that focuses on analyzing a problem and making necessary abstractions to solve the problem (National Academies of Sciences, Engineering, and Medicine, 2010). In the CT process, humans structure the solution of a problem in a manner that can be efficiently performed by an information-processing agent (Wing, 2010). However, in this process, humans do not replicate the thinking mode of computers (Wing, 2006). They focus on how to solve problems using computers rather than working directly with computer hardware; this process does not need absolute use of a computer or machine (Wing, 2008).

It is stated that CT is a basic skill individuals should develop in the 21st century (e.g., Ma et al., 2021) as it is important for the development of other skills such as mathematical literacy and problem-solving (e.g., Cui & Ng, 2021; Korkmaz et al., 2017; Ng & Cui, 2021; Voogt et al., 2015). CT allows individuals to solve complex and challenging daily life problems by utilizing information and computing, enhancing their analytical thinking skills, and carrying out problem abstraction (Qiu, 2009). Students' high level CT skills allow them to be engaged in the learning process at high levels (Li et al., 2012). In addition, the computational principles and problem-driven approach also enhance students' interest in computing (Hambruch et al., 2009).

CT can be taught within the context of various subjects, but it is preferred to be taught through programming (Lye & Koh, 2014) as students are directly exposed to CT when they engage in programming (Sabarinath & Quek, 2020). However, students often face challenges in reading and writing codes, tracing the codes in a systematic order, learning programming concepts and associating them, and writing programs (Xia, 2017). In order for students to learn programming (Sabarinath & Quek, 2020) and computing proficiently (Guzdial, 2008), teachers need to support their students with alternative teaching strategies in their studies. For this purpose, there

have been studies carried about online teaching of CT (e.g., Hsu et al., 2018; Jocius et al., 2022; Liu et al., 2023; Monteiro et al., 2019; Zitouniatis et al., 2023). Online activities are indeed suitable to the nature of coding itself, the pace of individuals' acts during coding, and the progression speed (Mikkonen, 2019). In addition, online sessions can facilitate student learning by providing additional sample solutions, hints, and feedback (Milicic et al., 2020).

Educational videos facilitate online learning experiences as they offer the opportunity to present knowledge in both visual and audio formats, thereby enriching the learning experience (Chen & Wu, 2015), encouraging further involvement of learners in the learning process (Bruce & Chiu, 2015), and flexibility of scheduling and pace (Howard et al., 2018). The features of video lectures such as pause, rewind, and replay provide students with the opportunity to cover the content at their own pace and in their preferred time (Hong et al., 2018). Students can catch up on missed classes (Jung & Lee, 2015), study for exams (Bonafini et al., 2017; Traphagan et al., 2010), learn how to solve specific problems (Jung & Lee, 2015), and review challenging concepts (Bonafini et al., 2017) through video lectures. Some students prefer video lectures to traditional courses as they can choose the content, the learning environment, and the time (Hill & Nelson, 2011). It has been revealed that in recent years, students with different academic levels prefer online videos to improve their learning performance (Jung & Lee, 2015).

In the literature, some studies revealed that video lectures had a positive effect on the learning performance of students (e.g., Dalal, 2014). However, some studies reported that video lectures do not promote the learning process of the students (e.g., Pal & Patra, 2021), or the effect of video lectures on the learning performance is not significant or explicit (e.g., Kim & Chen, 2011). It is considered that one of the factors that leads to the ambiguous effect of video lectures on student performance and the learning process is the type of knowledge in the content. In this context, the literature suggests that the type of knowledge should be considered as a factor in the design of video lectures (Hong et al., 2018; Höffler & Leutner, 2007; Wang et al., 2020).

CT includes both declarative knowledge, which involves learning and using ready-made commands in a programming language and procedural knowledge, which involves algorithm creation, loop structures, and program writing. Therefore, when designing video lectures during the CT instruction, it is important to consider the knowledge type. Some studies have been conducted on the opportunities provided by the video lectures in CT instruction, and it has been found that they offer opportunities for students to repeatedly watch the course content and make up for missed classes (Hsu et al., 2018). However, there haven't been any studies carried out yet about the use of different video lectures, considering the type of knowledge in the computational problem-solving practices, and comparing the outcomes in terms of online learning.

This study aimed to investigate the effect of different video lecture types on the computational problem-solving performances of students in online programming courses that include different type of knowledge. It is also aimed to reveal students' preferences for the use of different video lecture types in computational problem-solving practices. It is necessary to unveil the reasons why students favor or disfavor a specific video lecture type since instructors and information technology developers can understand how students perceive video lectures and can create and design desirable video contents that suit the specific needs of students (Pal & Patra, 2021; Shoufan, 2019).

2. Theoretical framework

2.1. Computational thinking

CT was initially introduced by Papert (1980) and popularized by Wing (2006). It is a problem-solving process that involves practices such as logical thinking, algorithmic thinking, abstraction, choosing the most appropriate strategy to solve a problem, and generalization (Computer Science Teachers Association & International Society for Technology in Education, 2011). Brennan and Resnick (2012) presented CT concepts that young children used during programming activities using a blockbased program as the following:

- Sequence: a series of individual instructions that can be executed by a computer to carry out a task,
- Loop: a mechanism that allows the same sequence to be repeated multiple times,
- Parallelism: the execution of different sequences of instructions simultaneously,
- Event: something that causes another thing to happen,
- Conditional: decision-making structures based on specific conditions,
- Operator: mathematical, logical, and string expressions that enable programmers to manipulate numbers and strings,

- Data: values stored, retrieved, and/or updated through variables or lists.

Brennan and Resnick (2012) defined the practices in which children were engaged during CT in the blockbased programming environment under four categories:

- Being incremental and iterative,
- Testing and debugging,
- Reusing and remixing,
- Abstracting and modularizing

In the context of being incremental and iterative, students structure the program in the series of small steps to accomplish a task. Testing and debugging requires to develop strategies to eliminate or diminish the problems that are detected in the program. This practice is related with reusing and remixing which requires to transfer something from the programs that were created by others or by getting support from someone who is experienced in programming. In the practice of abstracting and modularizing, programmers aim to build something extensive by combining small parts of the program together. This practice makes it easier for the programmer to think about different parts of the program, and easier for others to read and understand the program.

Weintrop et al. (2016) present a taxonomy that represents CT for mathematics and science and defined “computational problem-solving practices” as a category within this taxonomy. Computational problem-solving practices depend on the fact that enhancing students to understand scientific and mathematical events using programming can support them to improve their conceptual understanding about mathematical and scientific concepts.

Ng and Cui (2021) developed an analytical framework by combining the CT perspective of Brennan and Resnick (2012) which is related with child-friendly programming activities and the CT perspective of Weintrop et al. (2016) which is related with the intersection between CT and mathematical thinking practices. They combined the practices that are modeling, algorithmic thinking, debugging and troubleshooting in Weintrop’s et al. (2016) taxonomy with the CT practices defined by Brennan and Resnick (2012) as abstracting and modularizing, reusing and remixing, and testing and debugging. Thus, Ng and Cui (2021) formed an analytical framework to analyze the CT processes of students in problem-solving practices. In this framework, the computational problem-solving practices are categorized as the following:

- Modeling: using the representations to construct original concepts,
- Abstracting and modularizing: elaborating the problem-solving process considering various details,
- Algorithmic thinking: solving a problem step by step,
- Reusing and remixing: constructing something with the help of other products or ideas,
- Testing and debugging: checking the procedure and finding out the problematic parts if there are.

In our study, computational problem-solving practices were used during each video lecture in the context of both programming courses. In each practice, the computational problems were used that require CT concepts (Brennan & Resnick, 2012) to be used and the CT practices (Ng & Cui, 2021) to be implemented to build the program that produces a solution for the given problem.

2.2. Video lecture design

According to Chen and Wu (2015), there are different online video lecture types such as voice-over presentation, lecture capture, picture-in-picture, and Khan-style video. The voice-over presentation video lecture includes the audio recording of a lecture and the slides that present the content. The lecture capture video lecture consists of the instructor, the whiteboard, and the presentation notes. The picture-in-picture type consists of the image and voice of the instructor and presentation slides. Khan-style videos include handwritten notes and the voice of the instructor.

Considering the Social Learning Theory, Wang et al. (2020) posit that learners might experience higher levels of satisfaction when they see the instructor in the video lecture and social cues may enhance the understanding of conceptual information. They state that the instructor in the video may provide social cues such as glance or facial expressions, which could lead to an interaction between the instructor and the learner and help the learner achieve deeper learning. The instructor in a video lecture attracts the attention of students and facilitate the teaching of both easy and challenging topics (Wang et al., 2020).

Guo et al. (2014) argue that the presence of the human face stimulates more intimate and personal emotions and prevents the monotonous aspect of presentation slides. It is reported that lecture capture and picture-in-picture video lecture types are more effective than the voice-over presentation as they can better increase the learning performance of students (Chen & Wu, 2015). Pi and Hong (2016) report that video podcasts including PowerPoint slides with instructors lead to enhanced learning. Kizilcec et al. (2014) state that most students have a better video lecture experience when the video includes the image of the instructor. These results indicate that the existence of an instructor in videos improves students' learning experiences.

According to the cognitive theory of multimedia learning, the voice-over video lectures might split learners' attention (Chen & Wu, 2015) and learners may have cognitive load due to processing the image of the instructor (Homer et al., 2008). Wilson et al. (2018) argue that when an instructor presents a video lecture, students' attention and understanding may be negatively influenced due to the visual features of the instructor.

Hong et al. (2018) analyzed the effect of the existence of an instructor in video lectures when the video lecture included declarative knowledge or procedural knowledge. Declarative knowledge refers to "know-what", while procedural knowledge refers to "know-how" (Schunk, 1996). If an individual acquires declarative knowledge, then the individual comprehends and remembers the knowledge. If the individual acquires procedural knowledge, then this person has the related declarative knowledge and is also conscious about how to use it in a task to reach the aim. Hong et al. (2018) found that the existence of an instructor in a video lecture supported the acquisition of declarative knowledge but increased the cognitive load of the students in the learning of procedural knowledge.

Some studies focusing on video lecture design in online education have included students' views on different video lectures. It was determined that students' actual learning performance and their views about the efficiency of these lectures may conflict (e.g., Wilson et al., 2018). It is crucial to evaluate video lectures from the student perspective (Shoufan, 2019) and to identify the conditions under which students are satisfied during different video lecture types (Nagy, 2018). In addition to experimental studies, students' views should be asked about the effectiveness of video lectures in the learning process to conduct a comprehensive analysis of the effectiveness of different video lecture types in the learning process.

3. Aim of the study

In this study, it is aimed to investigate the effect of different video lecture types on the acquisition of different type of knowledge in the context of computational problem-solving practices. Considering the discrepancy between students' learning performance and their views of the teaching process, it is significant and necessary to obtain students' views for the sake of evaluating the impact of video lectures thoroughly on computational problem-solving performance. Hence, it is also aimed to assess the effectiveness of different video lecture types from students' perspective. In line with these aims, the following research questions were addressed:

RQ1: Is there a difference in the problem-solving performance of the students in computational problem-solving practices based on the video lecture type used for presenting the educational content

- consisting mainly of declarative knowledge?
- consisting mainly of procedural knowledge?

RQ2: Is there a difference in the preferences of students in computational problem-solving practices for the video lecture type used for presenting the educational content

- consisting mainly of declarative knowledge?
- consisting mainly of procedural knowledge?

4. Methodology

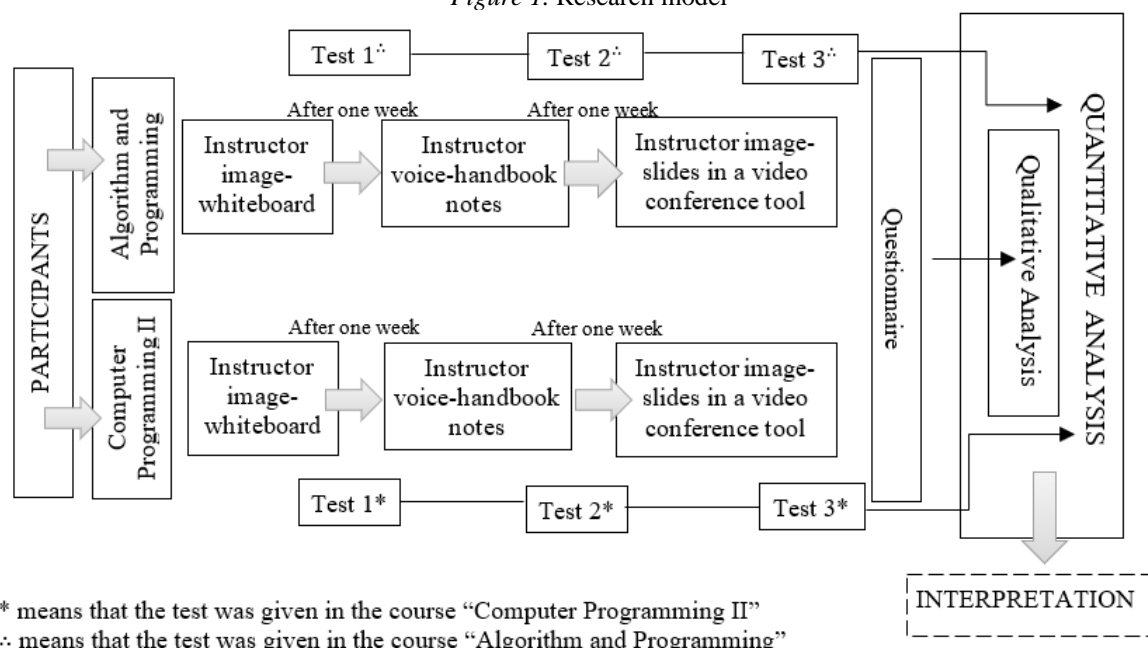
4.1. Experimental design

The study utilized the embedded design, which is a mixed method design (Creswell, 2012). The quantitative part of the research was conducted using the repeated measures design to address RQ1. It was investigated if there was a significant difference between the problem-solving scores of students after each practice. The practices were implemented one week apart (see Figure 1). The achievement test was administered in the following week of each practice. The one-way repeated measures ANOVA test was used to determine the differences between

the problem-solving scores of students. The qualitative part of the research was conducted to address RQ2. Content analysis was performed to reveal the preferences of the students regarding the video lecture type used for presenting the educational content. Finally, the results obtained from the quantitative and qualitative analyses were combined and interpreted (see Figure 1).

The participants were 41 university students enrolled in the Mathematics Education Program. Among the students, 19 were taking the Algorithm and Programming course, which mainly includes declarative knowledge about the principles of Maple commands applied in computational problem-solving practices. 22 students were taking the Computer Programming II course, which mainly includes procedural knowledge and covers the algorithm concept, flow diagram, and loop structures applied in computational problem-solving practices. Students in this study experienced learning through video lectures for the first time both throughout their college education in general and specifically in the context of computational problem-solving in Algorithm and Programming and Computer Programming II courses.

Figure 1. Research model



Three units with similar levels of difficulty were recorded for each course in three different video lecture types: (1) instructor image-whiteboard, (2) instructor voice-handbook notes, and (3) instructor image-slides in a video conference tool. The content covered in the video lectures is specifically related to the computational problem-solving, and it reflects the topics studied in the introduction of the Algorithm and Programming and Computer Programming II courses over three consecutive weeks. It was checked by the course instructor that the difficulty levels of the topics covered in the video lectures were parallel. In addition, the opinion of an instructor who is an expert in mathematics, mathematics education, and programming and who has taught computer programming courses for ten years was taken and it was assured that the subjects in the video lectures prepared within the context of each course were parallel and of the same difficulty level. Since Guo et al. (2014) indicated that shorter videos maintain students' attention and engagement, the video lectures were prepared as short videos of 15 minutes on average.

Algorithm and Programming and Computer Programming II courses were carried out through distance education, and all course materials, including lecture notes and presentations, were shared with students on the Moodle open-source learning platform. The video lectures were also made available to students on the Moodle open-source learning platform; the students were asked to watch each video within a week. At the end of each video lecture, the students were administered a test that assessed their problem-solving performance regarding the content of each video lecture. After all video-lecture presentations were completed, a questionnaire was administered to the students to allow them to evaluate the video lectures. In the questionnaire, the students were asked to make a preference order considering different types of video lectures and explain the reasons behind their preferences.

The researcher introducing the video lectures is the instructor for Algorithm and Programming and Computer Programming II courses. The role of the instructor in the presentation of these video lectures was to convey the

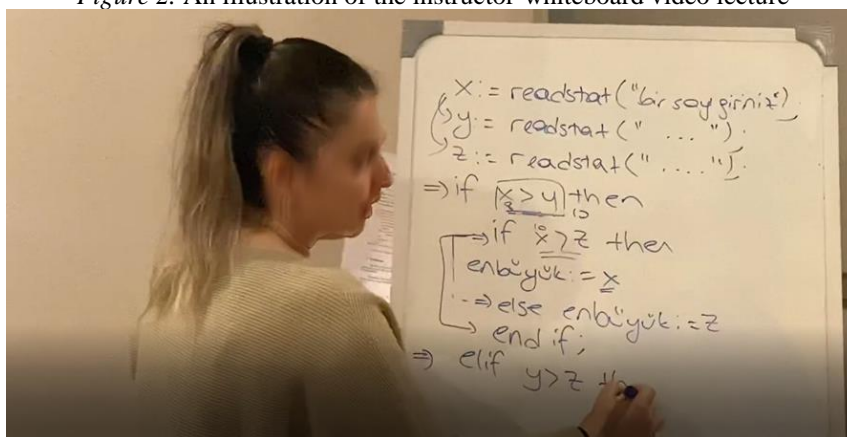
content. The instructor also monitored whether students watched the video lectures within the given time interval. The instructor prepared exams that evaluated whether students have learned the content presented in each video lecture in the context of each course and the questionnaire consisted of questions that evaluated whether students have liked or disliked the video lectures. After each video lecture, the researcher as the instructor administered the exam and finally the survey to students online and then assessed students' answers and views.

4.2. Video lecture types

The instructor has structured each of the three video lecture types in a way that conveys the computational problem-solving process and the relevant content to the students. The three types of video lectures used in the study are as follows.

(1) The instructor-whiteboard video includes a traditional lecture. The content is presented by the instructor on the whiteboard. The instructor's voice and image, and the way of transferring instructions via writing the notes on the whiteboard are recorded simultaneously using a digital video camera for online viewing (see Figure 2).

Figure 2. An illustration of the instructor-whiteboard video lecture



Throughout this video lecture, the instructor stands next to the whiteboard, and she explains the content to the students by constructing the computational problem-solving process including the relevant content step by step and cumulatively. During this process, the instructor writes down each computational problem-solving step on the whiteboard, linking it to the previous step and, she provides verbal explanations to further elaborate and clarify the content, and thus making it more understandable for the students.

The instructor faces the whiteboard while writing down the content and simultaneously provides verbal explanations. The instructor sometimes turns towards the camera, looking at it while verbally explaining the content written on the whiteboard. Throughout the video, students can see the instructor's face, glances, and body movements, as well as hear her voice clearly. They can also clearly see the content written on the whiteboard. In this context, this video lecture type includes the instructor's written notes on the whiteboard as well as her voice and image.

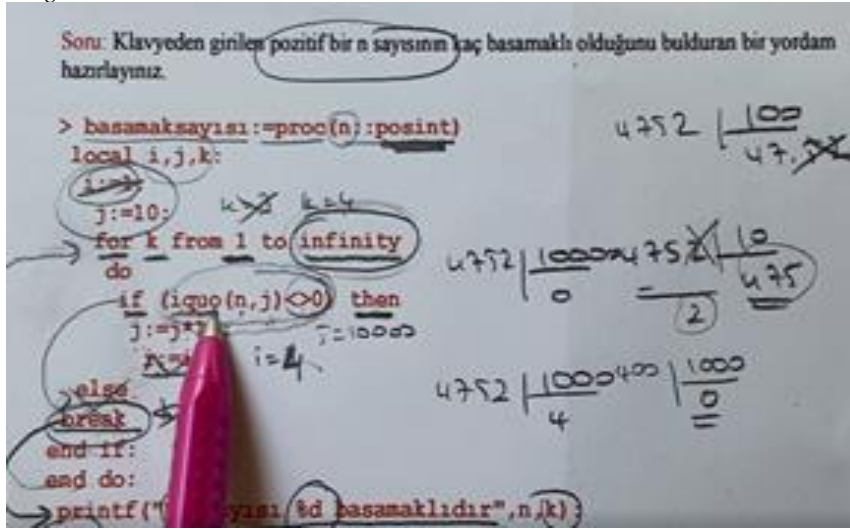
(2) Instructor voice-handbook notes is a kind of voice-over video lecture and can be defined as a speech-based lecture. It includes book notes, a voice-over explaining the notes, and a pencil used by the instructor to point out the content presented (see Figure 3).

In this video lecture, the camera captures the computational problem-solving process that includes the relevant content from the book, displaying it step by step on the screen. This allows the problem-solving process to be built by the instructor in a cumulative manner, like the instructor-whiteboard video lecture. The instructor has conveyed each step by relating it to the previous one.

During this process, the pen the instructor uses to highlight and point out important parts of the content is seen on the screen and the instructor's voice is heard as well. In this video lecture, the instructor's image is not present. The instructor writes additional notes on the book, performs mathematical operations required in the problem-solving process, and underlines the parts she wants to emphasize. At the same time, the instructor clarifies the

topic and enhances understanding by providing verbal explanations. In this context, the video lecture includes the instructor's book notes, which consists of written explanations made by the instructor on the book pages, verbal explanations, and the supplementation of the information in the book with voice-over explaining.

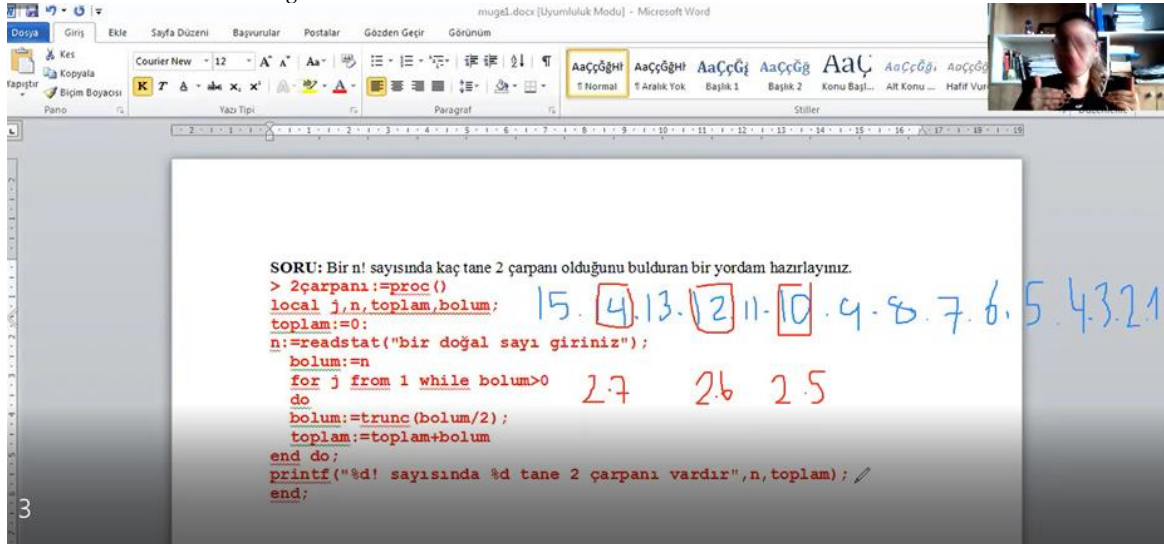
Figure 3. An illustration of the instructor voice-handbook notes video lecture



(3) The instructor-slides video lecture is recorded using a video conference tool and WebCam. It includes a combination of the image and voice of the instructor and the slides presenting the content to learners (see Figure 4).

The instructor uses the screen sharing feature of the video conference tool to display slides containing the content on the screen. Like the other two video lecture types, in this video lecture as well, the instructor builds the computational problem-solving process step by step and cumulatively, encompassing the relevant content. The image of the instructor is present in the upper right-hand corner of the slide, where the content is being presented. Students can see the instructor's face, glances, and hand movements, and hear her voice.

Figure 4. An illustration of the instructor-slides video lecture



The instructor can write additional notes on the slide that presents the content, make annotations, make marks, highlight the lines, and thus provide verbal explanations to the students in written form on the slide notes as well. In this context, this video lecture type includes a computer document containing the content, the written notes taken by the instructor, the instructor's image on a small screen and the instructor's voice.

4.3. Data collection tools

The instructor who prepared the video lectures developed achievement tests to evaluate whether the knowledge presented in the video lectures was acquired. The achievement tests included problems that required computational problem-solving practices, which are modeling, abstracting and modularizing, algorithmic thinking, reusing and remixing, and testing and debugging.

The achievement tests for the Algorithm and Programming course included problems that required declarative knowledge about the principles of Maple commands. The draft versions of the Test 1[☆], 2[☆], and 3[☆] were revised by a mathematics educator who is an expert in mathematics education and programming other than the researchers considering the mathematical content and if they included parallel problems or not. The achievement tests for the Computer Programming II course included problems that required procedural knowledge. The students were expected to use for loop, if then comparison statement, while loop, and/or for-while loop to solve the problems. The draft versions of the tests were revised by the same expert considering both the mathematical content and if the problems included in Test 1*, 2*, and 3* were parallel or not.

After completing all video-lecture presentations, the students were asked to evaluate the video-lecture types. In the questionnaire, students were posed questions as “When you evaluate the video lecture types in terms of their effectiveness and efficiency in your learning process, what is your preference for the use of these techniques in your learning process? Mark the video lecture type you find most useful as 1, and mark the one you find least useful as 3”, and “Are there any conditions when your preference would change? Please explain.” Two experts were consulted regarding the suitability of the questions in the questionnaire to the purpose of the study.

4.4. Data analysis

The CT processes of the students in the achievement tests were analyzed based on the criteria prepared by Urhan (2022) based on CT framework of Ng and Cui (2021) in mathematics education. Hence, the computational problem-solving processes of the students were analyzed based on the requirements of rationality components (Boero, 2006; Morselli & Boero, 2009).

It is determined that all of the students watched the video lectures within the designated time, and hence CT processes of all the students are included in the analysis. The scores of the students were calculated out of 100. The one-way repeated measures ANOVA test was used to determine if there was a significant difference between the problem-solving scores of the students depending on the video-lecture type.

Content analysis was performed on the qualitative data collected through the questionnaire, and the reasons that determined the order of preference for video-lecture types were revealed. In order to clarify the parts that were not understood in the data obtained from the questionnaire, the relevant students were contacted and these parts were clarified with interviews. Hence, participant confirmation was obtained. In Section 5, in which quotations from the students are presented to the reader, the students that took the Algorithm and Programming course were coded as P1, P2, ..., P19, while the students that took the Computer Programming II course were coded as P20, P21, ..., P41.

5. Findings

This section presents the results regarding the performances of students within the programming courses with different contents, the preferences of students for video lecture types, and the reasons they provided for their preferences. First, the results regarding the video lecture types that presented the content of the Algorithm and Programming course are provided, followed by the results regarding the video lecture types that presented the content of the Computer Programming II course. Since the two courses are not equivalent in content, we did not compare the results for two courses.

5.1. The results regarding the algorithm and programming course

The one-way repeated measures ANOVA was administered to determine if there was a significant difference in the computational problem-solving performance of the students across the three different video lecture types in the Algorithm and Programming course. Normality of the data was assessed using the Shapiro-Wilk Test, which

is more appropriate for small sample sizes (< 50 samples) (Field, 2009). Since the p -value was greater than .05, it was understood that the scores of students after each treatment were normally distributed (Field, 2009). The Mauchly's test was performed to assess sphericity. Since the p -value was .818 (> .05), we accepted the assumption that the variances of the differences between all possible pairs of within-subject conditions were equal. Thus, the assumption of sphericity has been met (Field, 2009). Table 1 presents the results of descriptive statistics for the independent variables.

Table 1. Descriptive statistics regarding the scores of students in the algorithm and programming course after each video lecture

	Mean	Std. deviation
Instructor voice-handbook	72.6316	18.88330
Instructor-slides	67.6316	18.13288
Instructor-whiteboard	61.0526	13.49680

The students obtained the lowest mean score in the instructor-whiteboard video lecture and the highest mean score in the instructor voice-handbook video lecture. The tests of within-subjects effects were performed to reveal whether there was an overall significant difference between the means for different video lectures. The results are presented in Table 2.

Table 2. Tests of within-subjects effects regarding the scores of students in the algorithm and programming course

Source		Type III Sum of Squares	<i>df</i>	Mean square	F	<i>Sig.</i>
Video type	Sphericity Assumed	1281.579	2	640.789	5.281	.010
	Greenhouse-Geisser	1281.579	1.954	655.763	5.281	.010
	Huynh-Feldt	1281.579	2.000	640.789	5.281	.010
	Lower-bound	1281.579	1.000	1281.579	5.281	.034
Error (video type)	Sphericity Assumed	4368.421	36	121.345		
	Greenhouse-Geisser	4368.421	35.178	124.180		
	Huynh-Feldt	4368.421	36.000	121.345		
	Lower-bound	4368.421	18.000	242.690		

Since the p -value was .010, it was deduced that the difference between the means was statistically significant [$F(2,36) = 5.281$]. Table 3 presents the results of the Bonferroni post hoc test, which enabled us to find the means that differed.

Table 3. The results of pairwise comparisons of the scores of students in the algorithm and programming course

Video type	(J) Video type	Mean difference (I-J)	Std. error	<i>Sig.^b</i>
Instructor voice-handbook	Instructor-whiteboard	11.579*	3.312	.008
	Instructor-slides	5.000	3.785	.609
Instructor-whiteboard	Instructor voice-handbook	-11.579*	3.312	.008
	Instructor-slides	-6.579	3.608	.255
Instructor-slides	Instructor voice-handbook	-5.000	3.785	.609
	Instructor-whiteboard	6.579	3.608	.255

Note. Based on estimated marginal means. *The mean difference is significant at the .05 level. ^bAdjustment for multiple comparisons: Bonferroni.

It was found that the mean score of the students in the instructor voice-handbook video lecture was significantly higher than their mean score in the instructor-whiteboard video lecture ($p = .008$), but no difference was found between the mean score of students in the instructor voice-handbook video lecture and that of the instructor-slides video lecture ($p = .609 > .05$). In addition, the mean score of the students in the instructor-whiteboard video lecture was not significantly different compared to the mean score of the students in the instructor-slides video lecture ($p = .255 > .05$).

5.2. The results regarding the computer programming II course

The one-way repeated measures ANOVA was performed to determine if there was a significant difference in the computational problem-solving performances of the students when the content was presented with three different video lecture types within the Computer Programming II course. The Shapiro-Wilk Test showed that the p -value was greater than .05 and the scores of the students were normally distributed (Field, 2009). In order to assess

sphericity, Mauchly's test was performed. Since the p -value was .742 ($> .05$), the assumption of sphericity has been met (Field, 2009). In Table 4, the results of descriptive statistics were presented for the independent variables.

Table 4. Descriptive statistics regarding the scores of students in the computer programming II course after each video lecture

	Mean	Std. deviation
Instructor-whiteboard	70.9091	14.11149
Instructor-slides	63.4091	25.51313
Instructor voice-handbook	55.4545	19.08060

It was seen that the students had the highest mean score in the instructor-whiteboard video lecture and the lowest mean score in the instructor voice-handbook video lecture. The results of the tests of within-subjects effects are presented in Table 5.

Table 5. Tests of within-subjects effects regarding the scores of students in the computer programming II course

Source	Type III Sum of Squares	df	Mean square	F	$Sig.$
Video type	Sphericity Assumed	2628.030	2	1314.015	6.083
	Greenhouse-Geisser	2628.030	1.943	1352.709	6.083
	Huynh-Feldt	2628.030	2.000	1314.015	6.083
	Lower-bound	2628.030	1.000	2628.030	6.083
Error (video type)	Sphericity Assumed	9071.970	42	215.999	.022
	Greenhouse-Geisser	9071.970	40.799	222.360	
	Huynh-Feldt	9071.970	42.000	215.999	
	Lower-bound	9071.970	21.000	431.999	

Since the p -value was .005, it was deduced that the difference between the means was statistically significant [$F(2,42) = 6.083$]. Table 6 presents the results of the Bonferroni post hoc test, which was performed to determine the means that differed significantly.

Table 6. The results of pairwise comparisons regarding the scores of students in the computer programming II course

Video type	(J) Video type	Mean difference (I-J)	Std. error	$Sig.^b$
Instructor voice-handbook	Instructor-whiteboard	-15.455*	4.055	.003
	Instructor-slides	-7.955	4.507	.276
Instructor-whiteboard	Instructor voice-handbook	15.455*	4.055	.003
	Instructor-slides	7.500	4.707	.378
Instructor-slides	Instructor voice-handbook	7.955	4.507	.276
	Instructor-whiteboard	-7.500	4.707	.378

Note. Based on estimated marginal means. *The mean difference is significant at the .05 level. ^bAdjustment for multiple comparisons: Bonferroni.

The mean score of the students in the instructor voice-handbook video lecture was significantly lower than the mean score of the students in the instructor-whiteboard video lecture ($p = .003$), but no difference was found between the mean score of students in the instructor voice-handbook video lecture and that of the instructor-slides video lecture ($p = .276 > .05$). In addition, the mean score of the students in the instructor-whiteboard video lecture was not significantly different compared to their mean score in the instructor-slides video lecture ($p = .378 > .05$).

5.3. Differences in students' order of preference and the reasons for their preferences

5.3.1. Algorithm and programming course

In the Algorithm and Programming course, the students were asked to evaluate video lecture types in terms of their effectiveness in the learning process, and to order the lecture types based on their preference. The order of students' preference based on the effectiveness of video lecture types and the order of video lecture types in terms of students' problem-solving performance were consistent. The students preferred the instructor voice-handbook video lecture type the most, and the instructor-whiteboard video lecture type the least. The factors

affecting their order of preference were grouped under the themes of attention, time, and type of knowledge. The themes are presented in Table 7.

Table 7. The factors affecting students' preferences of the video lecture types used in the algorithm and programming course

Themes	Quotations
Attention	<p>"The writing of commands is very technical. Parentheses, name of commands, semicolon, parameters, etc. I could not catch these details on the whiteboard. But when I saw the written lecture notes, I did not get distracted. It was easy and quick for me to focus on the details." [P9]</p> <p>"I think the audio and lecture notes are sufficient. I listened directly to the instructor's voice and followed the lecture notes. I was distracted by the instructor's image near the notes in the video conference technique. I was absolutely lost in the whiteboard video lecture type. I could not catch the details. I had to study from the book after the lecture." [P3]</p>
Time	<p>"I think it is a waste of time when the instructor writes the commands on the whiteboard one by one. She just writes the commands. It is not something extra, nor a solution. It's like putting what is in the book on the whiteboard. Going through lecture notes is much faster." [P11]</p> <p>"After learning the usage of the commands, I want to see different examples of their usage. It is impossible for us to see so many examples on the whiteboard during one session of the lecture. Therefore, I did not find the whiteboard technique efficient." [P7]</p> <p>"It is much better to go through the lecture notes. In the book, we can both clearly see the spelling of the commands and quickly go over many examples. We do not have that chance on the whiteboard. Write-erase-write again; time is not enough." [P3]</p>
Type of knowledge	<p>"The content of this course is not like problem solving or proving, in which the result of one step must be compatible with another. In these kinds of courses, it would be better if the instructor structured the process on the whiteboard, but this lesson is not like that. Learning the rules to function the commands is enough to apply them." [P8]</p> <p>"The information in the book is to the point. It is enough to learn and remember the commands. There is no need for the instructor to write the commands and to make extra explanations on the whiteboard." [P14]</p> <p>"All content is about the application of some rules to function the commands. I do not need any extra explanation, note and/or drawing on the whiteboard to learn how to apply the rule. The instructor's voice over the lecture notes is sufficient." [P9]</p> <p>"After learning the usage of the commands, I want to see different examples of usage instead of more explanation about usage. Therefore, I did not find the whiteboard technique efficient." [P16]</p>

As far as attention is concerned, the students stated that they could not catch the details and their attention was distracted after a while in the whiteboard technique. They found the audio narration over the lecture notes more useful as they could clearly see the technical writing of the commands. They stated that they could clearly see the details in the technical spelling of the commands in the lecture notes and they could focus on the details more easily and quickly. They emphasized that in the technique where the instructor explained the content on the whiteboard, they could not distinguish the details easily; therefore, they could not understand the subject completely.

As for time, the students stated that they wanted to examine many examples related to the use of the commands. They mentioned that the videos, in which the instructor gave a lecture through lecture notes, were more effective and efficient in terms of time management and progress in subjects. Hence, they preferred the videos, in which the instructor gave voice narration over lecture notes, both in order to see the spelling of the commands clearly and to examine many and various examples in a limited time.

Concerning type of knowledge, the students realized that declarative knowledge was predominant in the content of the course, and stated that the best learning tool for this information was the voice narration over the lecture notes. The students emphasized that the information required for command learning was presented in the exact flow in the book and it was unnecessary for the instructor to write this flow on the whiteboard. Therefore, they did not find the instructor-whiteboard technique efficient. They found the video lecture type, in which the flow was followed directly from the book and the declarative information was conveyed directly by the instructor's voice narration, more useful in this course.

5.3.2. Computer programming II course

In the Computer Programming II course, the students were expected to evaluate the video lecture types considering their effectiveness in the teaching process and make a preference order. The order of students' preference regarding the effectiveness of video lecture types and the order of video lecture types in terms of students' problem-solving performance were consistent. The students preferred the instructor-whiteboard video type the most, and the instructor voice-handbook video type the least. The factors affecting their order of preference were grouped under the themes of attention, revision opportunity, and type of knowledge. Table 8 presents the factors and some relevant quotations from student interviews.

Table 8. The factors affecting students' preferences for the video lecture types used in the computer programming II course

Themes	Quotations
Attention	<p>"Seeing the instructor on the screen while listening to the topic makes me more alert. Just following the lecture notes make it difficult for me to focus. I get lost in the flow." [P22]</p> <p>"Seeing the instructor, her movements and gestures while she is explaining on the whiteboard creates a more dynamic environment. Listening to a recording as a voice note is very monotonous. I mean, it is boring. After a while, I get sleepy and stop following the lesson." [P30]</p> <p>"When I did not see the instructor in the audio recording on the lecture notes and video conference technique, I took a break very often. But I did not want to break the instructor-whiteboard video lecture. I wanted to watch until the end." [P38]</p> <p>"When I was going through the lecture notes of the book, I was not able to focus on the part where we created the main loop. Although the instructor tried to draw my attention to that part while explaining it through the lecture notes, the ready-made lines confused me." [P26]</p>
Revision opportunity	<p>"The instructor both gave an oral explanation and wrote on the whiteboard. So, it was like we went over it twice. This repetition made me understand the subject better." [P32]</p> <p>"I didn't take notes myself in the audio recording over the lecture notes and video conference technique, just because the book notes are in the book anyway. However, in the technique where the instructor narrates on the whiteboard, I recorded what she wrote on the whiteboard in my notebook and took additional notes for myself. I watched the video once again, checked my notes to see if there was anything missing. I can say that the whiteboard technique gave me a chance to revise." [P29]</p>
Type of knowledge	<p>"Creating a loop is not like applying a ready-made rule or using commands. It's like knowing the concepts and solving problems using them. I found it more useful when the instructor explained it on the whiteboard rather than seeing the loop as a pre-made rule in the book." [P33]</p> <p>"It's like problem solving or proving. I think it would be more understandable if someone structured the process and explained it." [P26]</p> <p>"The loop is something that is built step by step. It is necessary to decide what to do, what steps to take to reach the goal and to think step by step. It was very hard for me to think step by step in audio recording over the ready-made lecture notes." [P39]</p> <p>"Book notes prevented me from setting up the process in my mind. The video conference technique was not much different; the lecture notes were ready-made, but while the instructor was explaining the content on the whiteboard, I felt that we were building the process step by step." [P35]</p>

Considering the theme of attention, the majority of the students stated that they could focus better and understand the subject more easily when they were listening to the content from the instructor and seeing the instructor simultaneously. The students emphasized that seeing the instructor allowed them to maintain their focus. They also mentioned that the instructor herself was a stimulant for them to focus on the flow, and they were lost in the video lecture conducted via audio recording over book notes as they could not see the instructor.

As for the theme of revision opportunity, in the video in which the instructor taught the subject on the board, the teacher's verbal and written explanation simultaneously enabled the students to better comprehend the subject and provided reinforcement. In the instructor voice-handbook and the instructor-slides in the video conference tool techniques, the students followed the notes while the instructor was speaking. However, they stated that it was not as effective and efficient for them in terms of understanding and repeating the content as following the notes that the instructor wrote on the whiteboard in her own handwriting.

As for type of knowledge, the students stated that the content of this course included procedural knowledge rather than declarative knowledge. Understanding procedural knowledge required detailed explanation and interpretation and creating loops. The students also emphasized that creating a loop or procedure also required creating small loops or comparison statements. They stated that they found the instructor-whiteboard technique more useful since they understood the task of creating piece-by-piece loops and then bringing them together on the whiteboard better. The explanations on the ready-made lecture notes made it difficult for them to decompose the loops.

6. Discussion and conclusion

Coding requires using both syntax rules and problem-solving strategies. Language syntax is the first thing to learn for programming and requires declarative knowledge. A deeper reflection on syntax facilitates the acquisition of procedural knowledge and the development of coding skills. In this study, the effect of video lectures on students' learning of declarative and procedural programming knowledge was investigated.

The study focused on two research questions: (1) Is there a difference in the problem-solving performance of the students in computational problem-solving practices according to the video lecture type used for presenting the educational content? and (2) Is there a difference in the preferences of students in computational problem-solving practices regarding the video lecture type used for presenting the educational content? The first research question aimed to determine whether students' problem-solving performances in computational problem-solving practices differed based on the video lecture. With the second research question, it was aimed to determine the effect of students' perceptions about the effectiveness of video lecture types on their computational problem-solving practices and to reveal the factors affecting their views.

Regarding the first research question, the students in the Computer Programming II course showed the highest performance in the video lecture where the instructor narrated on the whiteboard, followed by the instructor-slides in the video conference tool and the instructor voice-handbook notes technique. The students in the Algorithm and Programming course showed the highest performance in the instructor voice-handbook notes technique, followed by the instructor-slides in the video conference tool technique and the instructor-whiteboard video technique.

Regarding the second research question, when the effect of students' perceptions about the effectiveness of video lecture types on their computational problem-solving practices were examined, it was seen that they found the video lecture, through which they achieved highest performance, more beneficial, whereas they did not find the video lecture, with which they achieved lower performance, effective and efficient in terms of understanding the content of the course. Hence, in the Algorithm and Programming course, the students preferred the instructor voice-handbook video lecture type the most, and the instructor-whiteboard video lecture type the least, while in the Computer Programming II course the students preferred the instructor-whiteboard video type the most, and the instructor voice-handbook video lecture type the least.

Coding means the writing of computer programming code (Lye & Koh, 2014). According to Stephens (2018), programming can be defined as developing a logic-focused mindset by writing codes to record and execute algorithms in a formalized way. In this study, the Algorithm and Programming course, in which ready-made commands are taught, could be considered as coding, and the Computer Programming II, in which scripts are designed for a certain function, could be considered as programming. As stated by Mannila et al. (2014), we think that programming is an activity in which students perform more difficult tasks compared to coding.

Wang et al. (2020) reported that the presence of an instructor in a video lecture positively affects the learning of difficult topics. Ilioudi et al. (2013) also revealed that lecture capture was more effective compared to books for complex topics, and learning performance in lecture capture was higher than that in Khan-style video lecture. In our study, the students in the Computer Programming II course, which had a more difficult structure compared to coding in the Algorithm and Programming course, also became more successful after the instructor-whiteboard video lecture. Furthermore, the students who learned programming in the Computer Programming II course stated that the most suitable video technique for their learning process was the instructor-whiteboard video technique. The students, who learned to use ready-made commands in the Algorithm and Programming course, stressed that the content of the course had a mechanical structure that progressed in the form of input-output and required the use of declarative knowledge. They stated that the most suitable video lecture technique for this flow is the instructor voice-handbook notes technique.

It is reported in the literature that the presence of an instructor in a video lecture negatively affects students' attention (Wilson et al., 2018). In this study, the students who learned ready-made commands in the Algorithm and Programming course stated that they were distracted due to the visual presence of an instructor in the video lecture. Guo et al. (2014) stated that Khan-style videos were more engaging compared to PowerPoint slides. They reported that students' engagement improved when the video was shorter and the talking style was faster. In this study, the students in the Algorithm and Programming course found the instructor voice-handbook notes video technique more effective as it provided them with the opportunity to see more examples, ensured the transfer of knowledge with short, fast and clear explanations without wasting time on writing, presented them the technical usage and writing of commands in the clearest way, and did not include unnecessary verbal and written explanations.

As a result, the students found the technique, in which the instructor explained the content on the whiteboard, to be more useful in the lecture that included computational problem-solving practices based on procedural knowledge. However, the students found the video technique, in which the instructor was not present and in which they were exposed only to audio narration over the notes, to be more effective in the lecture which focused on the computational problem-solving practices containing mostly declarative knowledge. On the other hand, Hong et al. (2018) found that a video lecture that includes only the instructor facilitates the learning process of declarative knowledge, and cognitive load increases when students learn procedural knowledge. The study of Hong et al. (2018) was conducted in the context of an educational technology course, while this study focused on the computational problem-solving practices in mathematics. The difference between the results of the current study and the study of Hong et al. (2018) may depend on the topic taught.

It was seen that the effect of the presence of an instructor varied, depending on the type of knowledge taught in the instructional video focusing on the computational problem-solving practices. This result demonstrated that the selection of effective video types is influenced by the content. Similarly, Nagy (2018) argued that it is necessary to consider the content of the lecture to select the most effective video lecture type in the teaching process. In the context of computational problem-solving practices, it is recommended that the instructor should be present visually in the video lecture that includes mainly procedural knowledge. On the other hand, the audio-recording of the instructor over the lecture notes is more efficient and preferable in the video lecture that includes mainly declarative knowledge. Educators should consider these recommendations while designing online learning environments in the context of computational problem-solving since such a design would be consistent with the preferences of the students and also improve the problem-solving performance of students.

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Editorial note: Designing microlearning for how people learn

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ABSTRACT: Although the term *microlearning* has been around since 2005 (Hug, 2005), it has regained popularity in recent years due to the increasing mobility and competing priorities of adult learners. Today's learners seek smaller, focused lessons that deal with a single topic and can be consumed quickly. Yet, there are still many questions surrounding what microlearning entails, how it should be designed, who it is intended for, and how the learning in microlearning can be assessed. This special issue aims to explore the design, development, implementation, and assessment of microlearning, with an emphasis on designing microlearning experiences with today's learners in mind. After undergoing two rounds of rigorous reviews, four out of the 28 submissions received for this special issue were chosen for inclusion. This editorial note will introduce the special topic, analyze common themes across the selected papers, outline the procedures for paper solicitation and review, present summaries of the accepted papers, and synthesize the key findings.

Keywords: Microlearning, Micro-credentials, Mobile-based, Self-directed learning

1. Introduction

According to a recent report by the Association for Talent Development, “microlearning is one of the most widely discussed and debated trends in the learning industry” (ATD Research, 2017, p. 1, as cited in Corbeil et al., 2021b, p. 3). The explosive growth of social media over the past decade, as well as the abundance of mobile devices in the hands of learners and professionals will cause microlearning to quickly permeate educational and corporate learning environments as “personalized mobile learning through bite-sized learning snippets” (Corbeil et al., 2021a, p. xxiii).

While the applications of microlearning are becoming more popular and varied, there is consensus that creating microlearning is not as easy as dividing existing content into smaller chunks. As Kumar (2020) observes, “microlearning is not about chunking large pieces of content but designing a standalone piece of content that can be administered to learners for a holistic learning experience” (para. 12).

This special issue explores effective instructional and multimedia design principles and practices for the purposeful design, development, assessment, and implementation of microlearning for meaningful learning. This special issue will be of use to professionals, including designers, developers, and instructors, in all levels of online, blended, and mobile learning education and corporate learning environments.

An analysis of the accepted articles of this special issue identified four recurring themes:

- **Mobile-based microlearning:** Three of the articles focus on the use of mobile-based microlearning as a method to support adult learners and enhance instructional goals in various contexts, including workplace, higher education, and teacher professional development.
- **Flexibility and self-directed learning:** The articles highlight the importance of flexibility and self-directed learning in the context of microlearning. They discuss how microlearning offers convenience, enables learners to engage in brief, self-directed learning tasks, and promotes self-directed learning and extension of course content.
- **Integration of technology:** The articles emphasize the integration of technology, particularly mobile devices and online platforms, to facilitate microlearning. They discuss the challenges and benefits of incorporating technology in the design and implementation of microlearning experiences.
- **Design and assessment:** The articles discuss the design and assessment considerations associated with microlearning. They explore the design decisions, learning objectives, social dimensions, and assessment methods that need to be considered to ensure effective implementation and learner engagement with microlearning activities.

2. Paper solicitation and review

The call for manuscript proposals was published online on January 30, 2022. Of the 28 initial submissions, eight were excluded due to their lack of alignment with the special issue's focus or failure to meet ET&S standards. The remaining 20 manuscripts underwent two rounds of thorough evaluation and revision. Following the first round, eight articles proceeded to the Stage 1 review. Subsequently, these articles underwent a double-blind peer review process, leading to the identification of four exceptional manuscripts.

3. Accepted article summaries

Presented below are brief summaries of the articles that have been accepted for publication in this special issue.

3.1. A systematic review of mobile-based microlearning in adult learner contexts

This systematic review analyzes the empirical literature on mobile-based microlearning in adult learner contexts between 2015 and 2021. It explores the integration of mobile-based microlearning in workplace and higher education settings and highlights its effectiveness and design principles. The review concludes with recommendations for practitioners, emphasizing the importance of flexible learning options and the potential of mobile-based microlearning in supporting instructional goals.

3.2. How can you deliver microlearning when learners don't want it? Designing microlearning for socially oriented learners

This research study examines the impact of microlearning design decisions on employee learning in a professional development program. The study focuses on the case of microlearning lessons on inclusive teaching and analyzes participants' reflections, discussions, survey responses, and assessments. The findings suggest that microlearning can effectively support employee learning beyond the intended objectives, highlighting the importance of needs assessment, suitable learning objectives, social dimensions, and assessment in designing and assessing microlearning in line with learner preferences and workplace contexts.

3.3. Optional embedded microlearning challenges: promoting self-directed learning and extension in a higher education course

This case study examines the implementation of a microlearning system called *tech-flex challenges* in a higher education course. The study involved 85 students and 5 instructors in an educational technology course for preservice teachers. The findings reveal that while students had positive perceptions of the system, participation rates were low. Students who completed the microlearning challenges enjoyed them and were motivated to engage in them for learning purposes rather than for earning a micro-credential. Instructors suggested that making the challenges mandatory could increase attention and participation.

3.4. Creating the conditions for professional digital competence through microlearning

This study investigates the use of microlearning courses in online and blended learning modes as a teacher professional development (TPD) approach in Hong Kong. The study involves 32 preservice teachers in the English language education program and evaluates their digital competencies through questionnaires, interviews, and observations. The findings highlight the perceptions of preservice teachers regarding technology integration, challenges faced, and the need for personalized and hands-on training to meet diverse learning targets. The study also contributes to the development of conceptual frameworks for microlearning design in teacher professional development.

4. Summary: Cross-cutting themes in the findings

A careful review of the findings of the accepted articles identified five common themes. The articles demonstrate a generally positive impact of microlearning across various contexts, highlight the importance of instructional

design principles, emphasize the role of technology in enhancing microlearning experiences, address learner engagement and motivation, and emphasize the significance of self-directed learning in microlearning for extended knowledge and skill development. What follows is a summary of the five cross-cutting themes identified in the findings.

4.1. Effectiveness and benefits of microlearning

The articles highlight the positive impact and effectiveness of microlearning in various contexts, such as higher education, workplace settings, and teacher professional development. They emphasize that microlearning can support learner outcomes, enhance digital competence, and provide opportunities for self-directed learning and knowledge extension.

4.2. Instructional design principles

The articles emphasize the importance of adhering to fundamental instructional design principles when designing and implementing microlearning. They discuss the significance of needs assessment, learner analysis, adaptation to learner preferences, and creating a supportive and reflective learning environment.

4.3. Integration of technology

The articles highlight the role of technology in microlearning and its potential for enhancing learning experiences. They discuss the use of mobile devices, online platforms, and digital tools in delivering microlearning content and developing digital competence.

4.4. Learner engagement and motivation

The articles address learner engagement and motivation in microlearning. They discuss the role of learner preferences, social interaction, recognition through micro-credentials, and the impact of optional or mandatory microlearning challenges on learner participation and motivation.

4.5. Self-directed learning

The articles emphasize the importance of self-directed learning in microlearning. They discuss how microlearning tasks encourage and support self-directed learning skills, allowing learners to explore knowledge and skills beyond the regular course expectations and develop competence in using microlearning for professional development.

In summary, the cross-cutting themes in these articles revolve around the effectiveness and benefits of microlearning, instructional design principles, integration of technology, learner engagement and motivation, and the promotion of self-directed learning in microlearning contexts.

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A systematic review of mobile-based microlearning in adult learner contexts

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ABSTRACT: This systematic review examines the empirical literature published between 2015 and 2021 on mobile-based microlearning in adult learning contexts. The rapid shift to online learning in 2020 in response to the global COVID-19 pandemic has emphasized the need to explore flexible learning options for adult learners. The convenience of mobile-based learning has increased due to the prevalence and global access to mobile devices. Mobile-based microlearning is an emerging area of research, and in this systematic review we explore ways adult learning contexts – including workplace and higher education – have integrated mobile-based microlearning to support instructional goals. We synthesize nine articles about mobile-based microlearning highlighting findings and implications for facilitators. Our findings showed that mobile-based microlearning is being implemented in various instructional contexts and the included studies focused on effectiveness and design principles. We conclude our review with recommendations for implications for practice.

Keywords: Microlearning, Mobile-based microlearning, Just-in-time training

1. Introduction

Mobile-based microlearning has become popular in the workplace and higher education settings (Lee et al., 2021; Leong et al., 2021; Zhang et al., 2016). This approach leverages the convenience of mobile devices and provides learners with immediate access to the essential training and resources necessary to achieve their goals efficiently. By breaking content into smaller chunks, it allows for rapid retrieval of information, which is critical in contexts such as information technology, the medical field, or other workplaces (Dabbagh & Fake, 2017; Gerbaudo et al., 2021; Lee, 2021; Smith et al., 2020). Wen and Zhang (2015) explain that microlearning can provide selective and personalized learning according to students' needs, enabling them to learn and fill in knowledge gaps. An essential aspect of microlearning is smaller content sizes and the learner's ability to interact with the content (Epp & Phirangee, 2019; Gerbaudo et al., 2021; Voss, 2021). Developing competency is particularly critical in workplace settings where workers must constantly maintain and refine their competencies (Gerbaudo et al., 2021; Moore, 2020; Zhang et al., 2016). Moreover, the time and speed of learning can be adjusted to individual learners, improving their retention and recall (Bruck, 2006).

Microlearning is not a new concept, and mobile-based microlearning is an evolution of the approach that has aligned with the prevalence and technological advances of mobile-based devices such as smartphones and tablets. Lin (2023) predicts there will be more than 7.5 billion smartphone users by 2026. Mobile-based microlearning combines the advantages of mobile learning and microlearning (Lee et al., 2021; Nikou & Economides, 2018), allowing personalized, adaptive, ubiquitous, and context-aware instruction (Bruck et al., 2012). Mobile-based microlearning has gained popularity for its ability to deliver skill-based information when needed (Bruck, 2006; Gerbaudo et al., 2021; Jahnke et al., 2020; Lee et al., 2021). The format of mobile-based microlearning can take many forms, including reflection, performance support, goal reminding, and task assignments (Gerbaudo et al., 2021; Taylor & Hung, 2022; Thalheimer, 2017; Voss, 2021). Moreover, in mobile-based microlearning, the content can be personalized, adaptive, and context-aware through the small screens of smartphones (Bruck et al., 2012). Studies show that mobile-based microlearning improves learners' efficiency, performance, engagement, and teaching approaches (Aitchanov et al., 2018; Dai et al., 2018; Göschlberger & Bruck, 2017; Jahnke et al., 2020; Ma, 2016). For adults and workers, mobile-based microlearning may provide increased flexibility to apply factual knowledge to skills required for the job (Decker et al., 2017).

As with any instructional approach, there are challenges with using mobile-based microlearning. For example, presenting too much information on small screens can result in eye strain (Sharma & Singh, 2022). In terms of learning effectiveness, using a mobile device may distract the learner, given the opportunities for misuse for other purposes such as enjoyment (Abdelaziz, 2020; Andoniou, 2017). Other pitfalls exist with technology, accessibility, and affordability (Jahnke et al., 2020). In addition, adopting new technology can be challenging for teachers or instructors unfamiliar with the digital environment because it requires time-consuming technical skills (Moore, 2016a; Oyarzun et al., 2020). This systematic review aims to synthesize the empirical research focusing specifically on workplace and higher education settings, which need more research attention.

1.1. Prior systematic reviews

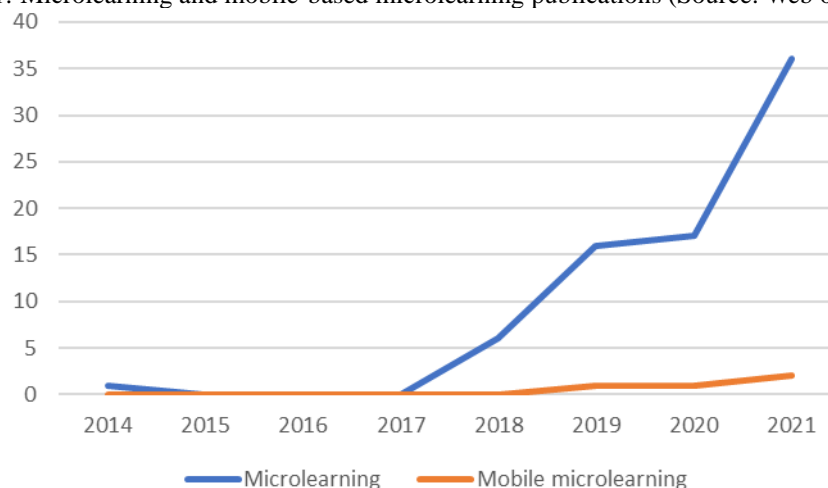
Our work builds off previous work focused on microlearning (Jahnke et al., 2020; Lee, 2021; Taylor & Hung, 2022) with a few key differences. Jahnke's et al. (2020) systematic review focused on microlearning's design challenges and principles. Jahnke et al. searched 2013-2017 and included 50 articles across five databases with conference proceedings. They also looked at academic articles as well as industry literature. In their review, they synthesized 15 design principles included in mobile microlearning, spanning usability issues and instructional flow. While this was an important focus, we were particularly interested in learner outcomes.

While Taylor and Hung (2022) were also interested in adult contexts, they did not include "mobile-based" as part of their search strings. Taylor and Hung sought to determine the trends and effects of microlearning. This search was conducted in 11 databases from years 2009-2020 and included 13 peer-reviewed articles. These 13 articles were then further classified into three categories of microlearning: short lessons, just-in-time (JIT), and flash lessons; all employed a range of instructional strategies including demonstration, gamification, and question and answers. They discovered that microlearning has apparent effects on knowledge and skills acquisition, increased learner confidence, and an increased utilization of microlearning materials beyond their required use. However, they omitted "mobile-based" as part of their search strings, stating that most microlearning was not designed to fit small screen mobile devices.

Lee's (2021) systematic review included K-12 contexts and excluded studies that used tablets and iPads. Lee's review included 26 articles from five academic databases and examined the purpose, source, impact, setting, and outcomes of the 26 mobile microlearning articles. Results of the review indicate an increase in student performance and motivation with a notable increase in knowledge retention. While this information is valuable, Lee only explored K-12 contexts and excluded studies that used tablets and iPads. Our review aims to discover any advances in microlearning since this previous work within the use of mobile devices and tablets.

Global smartphone usage is exploding, and the convenience of content and instructional materials in mobile formats addresses equity and access issues (Lin, 2023; Statista, 2023). The prior systematic reviews about microlearning omitted the critical mobile-based context or only looked at it in K-12 contexts. We acknowledge the instructional and design challenges of delivering content for small screens, but do not consider this an insurmountable challenge. We found that the interest in microlearning is trending upwards as evidenced by the increase in publications starting around 2017 (Figure 1). While the number of publications focused on mobile-based microlearning is increasing slower, we attribute part of that to the lack of understanding of the design challenges and implementation approaches for mobile-based microlearning. Global smartphone usage will only expand in the coming years, and course facilitators and designers need to understand ways of leveraging these devices for instructional purposes.

Figure 1. Microlearning and mobile-based microlearning publications (Source: Web of Science)



1.2. Purpose

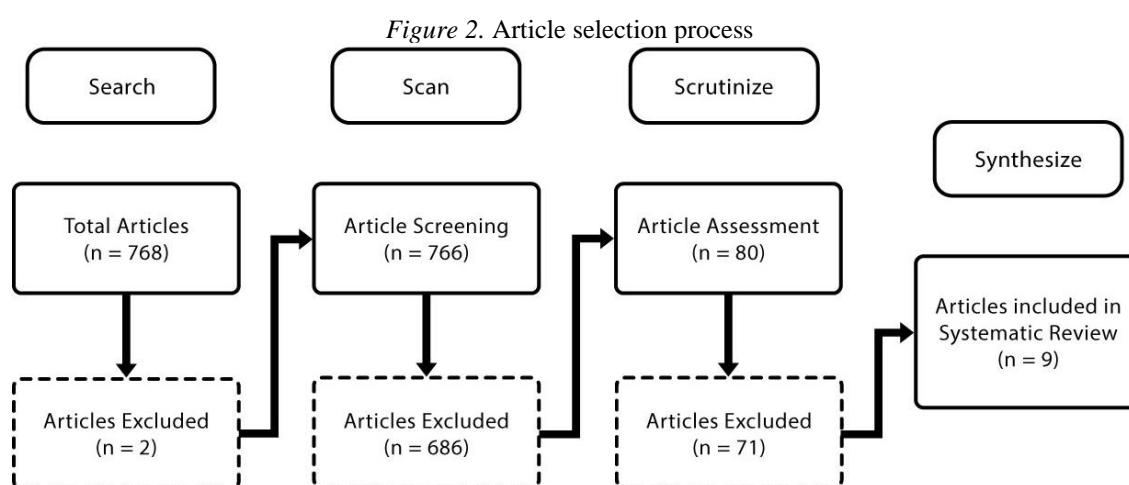
To address the lack of understanding around implementation approaches for mobile-based microlearning, we conducted a systematic review to examine mobile-based microlearning in adult contexts – specifically in the workplace or higher education. We were interested in how adult learners use mobile-based microlearning to

support their learning objectives. We also wanted to extend the prior work that has been done and provide synthesis on several aspects, specifically best practices for implementing mobile-based microlearning. We intend our findings to be helpful for those considering this approach and to encourage additional empirical research on implementations in various contexts. We selected a start date of 2015 to align with the increases in global mobile device usage (Lin, 2023; Statista, 2023), the upward trend of microlearning publications (Figure 1 above), and prior systematic reviews (Lee et al., 2021). Our systematic review will answer the following questions:

- In what instructional contexts or settings has mobile-based microlearning been implemented?
- What are the key findings from the implementations?

2. Methods

We conducted a systematic review of empirical articles to answer our research questions and used the PRISMA principles (Liberati et al., 2009) to guide the article selection process (Figure 2). Following the PRISMA guidelines allows for a transparent article selection process and establishes trustworthiness (Moore & Miller, 2022; Page et al., 2021).



2.1. Search

Our search was conducted in September 2022 using the Academic Search Premier and Education Source databases to identify peer-reviewed articles published between 2015 and 2021 with the following search strings: (“micro*” OR “just in time” OR “just-in-time”) AND (“mobile*”) AND (“workplace*” OR “train*” OR “learn*”). The “*” is used for wildcard searches. We defined “mobile” as any hand-held device including smartphones and tablets. These databases are commonly used for education-focused systematic reviews (Moore, 2020; Moore et al., 2023). These searches returned 768 studies, and we removed two duplicates, leaving us with 766 remaining.

2.2. Scan

We focused our systematic review on peer-reviewed empirical articles. We did not consider dissertations or conference proceedings for this review. When crafting the search strings for a systematic review, broad terms are helpful because it is not always clear how an author would define a specific term. During this second phase, we can scan the abstracts and filter down to the contexts we are most interested in. Our focus was on adult learners and we removed abstracts that either did not focus on adult learners (e.g., K-12 contexts) or were not about mobile-based microlearning. We used a broad definition of mobile in the search and then reviewed how microlearning was used to ensure it was on a mobile device. The latter focus resulted in most articles being excluded at this stage. Other common reasons included being a systematic review, not in the adult learner contexts, or not microlearning. This process removed 686 articles.

2.3. Scrutinize

There are typically two ways that articles are evaluated for quality – one is by filtering the initial search to specific high-quality journals (Crompton & Burke, 2018; Martin et al., 2020; Moore, 2022) and the other is by filtering screened abstracts by Q1 or Q2 journals (Bano et al., 2018; Moore, 2020; Moore et al., 2023). We decided to use the latter approach to ensure high-quality peer-reviewed research and narrowed our pool to only include articles published in Q1 or Q2 journals as ranked by SCImago (<https://www.scimagojr.com/journalrank.php>). The SCImago rankings use information from the Scopus database. This narrowing removed 28 articles from the pool. At least two authors reviewed each of the remaining articles based on the inclusion and exclusion criteria (Table 1). The first author resolved any conflicts, and collaboratively, all three authors reached a consensus on each article. Ultimately, we removed 43 articles – 22 were not about educational contexts, 16 were not about mobile-based microlearning, and five were not empirical. This final removal left nine articles that are included in our study.

Table 1. Inclusion and exclusion criteria

INCLUDE if ALL the following TRUE	EXCLUDE if ANY of the following TRUE
Published in English	The result is a dissertation, conference proceeding, or other non-peer-reviewed source.
Published between 2015 and 2021	The study provides insufficient details on the connection between mobile-based microlearning and an instructional context.
Published in a Q1 or Q2 peer-reviewed journal*	
Empirical study focusing on mobile-based micro-learning in the workplace or higher education contexts.	

Note. *Source: SCImago Journal and Country rankings (<https://www.scimagojr.com/journalrank.php>)

2.4. Synthesize

The results of synthesizing the nine articles are discussed in the following sections. Five of the articles measured specific learning outcomes (Joynes & Fuller, 2016; Lee et al., 2021; Wang et al., 2020; Wen & Zhang, 2015; Zhang et al., 2016), while four others focused on student perceptions of the design or usability of the microlearning technology (Dabbagh & Fake, 2017; Gerbaudo et al., 2021; Neffati et al., 2021; Voss, 2021). Because we used “mobile-based” as one of our filter requirements, we use microlearning and mobile-based microlearning interchangeably in the preceding sections. Where appropriate, we have added additional context through citations.

3. Results

We searched for empirical peer-reviewed articles published between 2015 and 2021 that investigated the support of educational goals – in both workplace and higher education contexts – through the integration of mobile-based microlearning. 2016 and 2021 were the most common publication years, with none published during 2018 or 2019. The recent trend of publications in 2021 suggests that mobile-based microlearning is an emerging educational concept and will continue to be researched and investigated. The publications were in various outlets, including journals focused on STEM (engineering, microprocessors, physics), medical, music, and educational technology contexts.

3.1. RQ1: In what instructional contexts or settings has mobile-based microlearning been implemented?

The included studies showed the diversity of contexts in which mobile-based microlearning has been implemented (see Table 2).

The implementation of mobile-based microlearning in undergraduate physics courses (Wang et al., 2020), computer software courses (Wen & Zhang, 2015), and medical education (Neffati et al., 2021) highlights potential applications for enhancing learning experiences across various disciplines. One significant advantage of mobile-based microlearning is the provision of on-demand resources, particularly beneficial in workplace environments (Gerbaudo et al., 2021; Zhang et al., 2016). This demonstrates that mobile-based microlearning can address individuals’ specific learning needs and challenges in professional settings. Mobile-based

microlearning in clinical and medical settings (Joynes & Fuller, 2016; Neffati et al., 2021) indicates its potential for improving medical education and enhancing clinical curriculum resources. Examining how faculty and instructional designers can benefit from microlearning resources (Dabbagh & Fake, 2017) suggests that mobile-based microlearning approaches can also support educators and instructional designers enhance their teaching practices and design practical learning resources.

Table 2. Contexts for included articles

Context	Article(s)
STEM Courses	Wang et al., 2020; Wen & Zhang, 2015
Workplace	Gerbaudo et al., 2021; Zhang et al., 2016
Clinical and Medical	Joynes & Fuller, 2016; Neffati et al., 2021
Journalism Courses	Lee et al., 2021
Music Courses	Voss, 2021
Faculty and Instructional Designers	Dabbagh & Fake, 2017

Each included study involved the development of a platform or curating resources into a repository to be implemented and used by the target audience. This development included courses (Lee et al., 2021), mobile platforms (Wang et al., 2020; Wen & Zhang, 2015; Zhang et al., 2016), mobile apps (Dabbagh & Fake, 2017; Neffati et al., 2021), and curated resources (Gerbaudo et al., 2021; Voss, 2021). Wang et al. (2020) focused their implementation in an undergraduate physics course. Wen and Zhang (2015) designed a microlecture platform to support learners in computer software courses. Notably, one of the advantages of microlearning is the ability to provide on-demand resources which can be particularly helpful in workplace environments (Gerbaudo et al., 2021; Zhang et al., 2016). Zhang's et al. (2016) study focused on designing a work-based learning platform for factory or office settings, and Gerbaudo's et al. (2021) study focused on creating a media platform for IT professionals. The clinical and medical settings were explored (Joynes & Fuller, 2016; Neffati et al., 2021). Neffati et al. (2021) developed a mobile e-learning app for medical education, and Joynes and Fuller (2016) developed microlearning resources for a clinical curriculum. Lee et al. (2021) described how they developed a mobile microlearning course for journalism students. Voss (2021) explored how just-in-time resources could be implemented to support students learning about music production. Dabbagh and Fake (2017) examined how faculty and instructional designers could benefit from microlearning resources.

3.2. RQ2: What were the key findings from the implementations?

Overall, the implementations were positively received in each of the studies. We found two themes of effectiveness—design principles and behaviors—in the articles (Table 3).

Table 3. Implementation themes of included articles

Theme	Articles
Effectiveness	Lee et al., 2021; Wang et al., 2020; Wen & Zhang, 2015; Zhang et al., 2016
Design Principles	Dabbagh & Fake, 2017; Gerbaudo et al., 2021; Joynes & Fuller, 2016; Neffati et al., 2021; Voss, 2021; Zhang et al., 2016

3.2.1. Effectiveness of mobile-based microlearning

Several of the included studies focused on the effectiveness of mobile-based microlearning (Lee et al., 2021; Wang et al., 2020; Wen & Zhang, 2015; Zhang et al., 2016). Wang et al. (2020) found that their mobile-based microlearning intervention for college physics content improved final exam mean scores and exam pass rate for students compared to the control group only receiving face-to-face teaching. Lee et al. (2021) confirmed that a mobile micro-course appealed to learners, improved their test scores, reduced the guessing rate, and enhanced learners' self-efficacy in news writing skills. Zhang et al. (2016) found that 84% of participants completed a work-based mission with a newly designed mobile system (WoBaLearn) for work-based learning. Furthermore, when the learners were assigned to redo the mission one week later, all participants who had completed the first mission could recall and succeed again. Wen and Zhang (2015) concluded that introducing Microlecture Mobile Learning System (MMLS) decreased course difficulty and increased interest and intelligibility in computer software courses. Additionally, the learners in MMLS exhibited higher average scores in the final exam compared to learners in the classroom.

3.2.2. Design principles in various contexts

Another emerging theme focused on design principles of mobile-based microlearning (Dabbagh & Fake, 2017; Gerbaudo et al., 2021; Neffati et al., 2021; Voss, 2021; Zhang et al., 2016). Gerbaudo et al. (2021) proposed a new online video model following Design Thinking methodology. The study respondents evaluated the enhanced video format as superior to other videos when learning how to solve IT problems. Neffati et al. (2021) designed an Augmented Reality platform for software engineering learners. In certain studies, contextualization in system design for personalization was emphasized. Zhang et al. (2016) described the system design, implementation, and evaluation methods and results of a work-based learning mobile system (WoBaLearn). Their focus was on a context-aware mobile learning system that enables personalization and adaptation processes for learners. Dabbagh and Fake (2017) attempted to design a mobile recommender system to align instructional strategies with learning technologies, targeting instructional designers and faculty. They noted different organizations may have different contextual needs that should be further explored. Voss (2021) designed a mobile application where just-in-time learning was provided for music recording production. This pilot study derived six design principles: task specific, concise, contextual, visual, diverse, and integrated. Joynes and Fuller (2016) investigated the impact of mobile learning resources in a mobile learning program (MBChB Mobile). In the program, mobile learning was a compulsory part of the course to maximize students' engagement, and the analysis showed that social and cultural norms can influence mobile behaviors. However, the authors caution that microlearning resources must complement, not replace, paper-based resources.

4. Discussion

This section provides the implications for practice that emerged from the included studies.

4.1. Implications for practice

Mobile-based microlearning offers many advantages, but implementing and developing this type of learning requires careful planning on the instructor's part. Mobile-based microlearning will require many of the same considerations that course designers need to consider when developing online courses (Moore, 2016a; Oyarzun et al., 2020). Creating a comprehensive microlearning curriculum or platform can require significant effort, particularly if it involves developing a new platform (Wang et al., 2020; Wen & Zhang, 2015; Zhang et al., 2016). Using a pilot approach and starting small in developing and using mobile-based microlearning can be useful. Instead of creating an entire course, consider doing one section or activity, engaging students in feedback, and building upon those efforts (Moore, 2016a; Moore, 2016b; Oyarzun et al., 2020). This approach allows an iterative design process that can focus on a specific topic or learning objective, ensuring that the microlearning content is concise, targeted, and aligned with the desired learning outcomes. By implementing the microlearning intervention and seeking input from learners, facilitators can assess the approach's effectiveness, identify areas for improvement, and gain insights that can inform future iterations and refinements of the microlearning resources. This iterative process allows for continuous improvement and ensures that subsequent microlearning modules or lessons are more tailored and to the learners' needs. This approach enables more efficient resource allocation, better alignment with learning outcomes, and informed decision-making for future scalability and implementation efforts (Moore, 2016b). The implications of this research highlight the potential of mobile-based microlearning in diverse contexts, including various disciplines, workplace environments, clinical and medical education, journalism education, music production education, and supporting educators and instructional designers. The findings underscore the adaptability and versatility of microlearning in meeting the specific learning needs of different target audiences. Based on these implications and findings, we encourage course facilitators to consider how they can use microlearning to complement existing instruction and personalize feedback to learners as they engage with this content.

4.1.1. Complement existing instruction

When considering the content to be used with microlearning, course facilitators should consider how it can complement existing instruction. Mobile-based learning presents opportunities for linking the instruction to authentic contexts (Lee et al., 2021; Wen & Zhang, 2015) which has been shown to be particularly effective for online instruction (Lowell & Moore, 2020; Moore, 2016a; Oyarzun et al., 2020). By framing the mobile-based content as complementary content, learners can fill their knowledge gaps at a time that is most convenient to them (Dabbagh & Fake, 2017; Voss, 2021; Wen & Zhang, 2015). This will maximize the effectiveness of

mobile-based learning as learners are able to take advantage of the just-in-time nature of these complementary resources (Gerbaudo et al., 2021; Voss, 2021). A key advantage of microlearning is that it provides learners with greater autonomy and flexibility in choosing their preferred method of receiving instruction. Allowing learners to select the microlearning modules or resources that align with their needs and preferences makes them more engaged and motivated, leading to improved learning outcomes (Epp & Phirangee, 2019; Wen & Zhang, 2015). Moreover, using microlearning as a complementary resource can enhance the accessibility and variety of learning materials.

4.1.2. Personalizing feedback

Pairing the just-in-time access to the information also creates opportunities to provide adaptive and personalized feedback to learners (Lee et al., 2021). This convenience makes the content available exactly when the learner needs it, and where possible, automated feedback should be implemented. This feedback will ensure that learners make the necessary connections between knowledge acquisition and their application to practice (Gerbaudo et al., 2021; Korkmaz & Boling, 2014; Lee et al., 2021). And while automated feedback can be valuable, personalizing the feedback to learners can help them adjust their learning behaviors (Lee et al., 2021). This personalized feedback considers each learner's specific needs, strengths, and areas for improvement, enhancing their engagement, motivation, and understanding of the content. By leveraging microlearning to deliver personalized feedback, educators can create a more individualized learning experience that promotes meaningful and targeted learning outcomes.

5. Limitations

A systematic review reflects the authors' decisions from framing the research questions through the article filtering decisions. To establish the validity of the systematic review, we implemented the PRISMA guidelines (Liberati et al., 2009; Page et al., 2021). These guidelines allow for a transparent search and article selection process that ensures future researchers can extend our work. A limitation of our research is our reliance on peer-reviewed sources. Another limitation was our criteria for high-quality articles and basing that on the ratings of the journals. While this did remove several articles, we felt that this approach was essential to aid in synthesizing high-quality work. We encourage other researchers to consider ways to evaluate article quality and refine our inclusion and exclusion criteria as they see fit. As indicated by the Web of Science publication report, there is growing interest in microlearning, and we wanted to establish a baseline for mobile-based microlearning synthesis. As more articles that focus on mobile-based microlearning are published in the coming years, researchers will have more opportunities to categorize and distill the research literature. While we found many articles referencing "mobile-based" and "microlearning" in titles and abstracts, our scan found that many lacked detailed focus on the learner outcomes or were not situated in adult learning contexts. This lack of focus suggests that while microlearning has broad interest, the research on mobile-based microlearning is still nascent in educational contexts.

6. Conclusion

This systematic review examined how mobile-based microlearning has been implemented in higher education and workplace contexts. We found that the flexibility of mobile devices has allowed for creative and innovative ways to provide just-in-time resources to learners across various contexts. Mobile-based microlearning has been used in academic and professional settings and fields of medicine, IT, music, instructional design, journalism, and physics, among others (Dabbagh & Fake, 2017; Gerbaudo et al., 2021; Lee et al., 2021; Neffati et al., 2021; Voss, 2021; Wang et al., 2020). All the articles showed evidence of a gain in learner outcomes or a positive impact on student perceptions of the technology. The number of 2021 articles in our study suggests a growing interest in mobile-based microlearning in higher education and professional settings. We invite future researchers to continue to empirically explore how microlearning can provide opportunities to support the diversity of adult learners' needs.

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How can you deliver microlearning when learners don't want it? Designing microlearning for socially oriented learners

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ABSTRACT: What do you do when employees want sustained, in-person, dialogic learning opportunities, but the realities of their work prevent participation in such learning events? Microlearning can offer an important solution to this conundrum but also requires careful navigation between design recommendations, learner preferences, learning objectives tied to work tasks, and assessment. This concurrent mixed methods research study uses identical convenience sampling to answer the research question: How is employee learning impacted by microlearning design decisions made to address fundamental contradictions presented by learner preferences and workplace contexts? This study focuses on the case of microlearning lessons on inclusive teaching in a professional development program for faculty at a small comprehensive university in the southeastern United States. Eleven participants' reflections, contributions to asynchronous discussions, responses to a post-program survey, and submissions on pre- and post-lesson assessments were analyzed through qualitative coding and descriptive and inferential statistics. While quantitative data analysis revealed significant participant learning aligned with lesson objectives, qualitative analysis revealed that learners also engaged in learning beyond these learning objectives. Complementing extensive literature on microlearning for procedural learning, this study provides new insights related to needs assessment, suitable learning objectives, social dimensions, and assessment of microlearning and offers recommendations for designing and assessing microlearning when adapting it to learners' preferences and workplace contexts.

Keywords: Faculty development, Inclusive teaching, Instructional design, Microlearning, Peer learning

1. Introduction

What do you do when employees want sustained, in-person, dialogic learning opportunities, but the realities of their work prevent their participation in such traditional learning events? Microlearning offers an important solution to this conundrum. However, it also requires careful navigation between design recommendations, learner preferences, and the need for assessing learning. It may also require adroit handling of learning objectives centered on complex problem-solving tasks (Corbeil et al., 2021; Jahnke et al., 2020; Sozmen, 2022; Taylor & Hung, 2022; Zhang & West, 2020).

A case for examining these challenges was provided by a small comprehensive university in the southeastern United States when needs assessment prompted the design and development of a new professional development program on inclusive teaching for faculty. While inclusive teaching has typically been addressed through lengthy, dialogic, in-person training, challenges such as limited faculty time called for consideration of a microlearning intervention intended as standalone training (Taylor & Hung, 2022; Torgerson, 2021; Torgerson & Iannone, 2019). The design of 13 microlearning lessons, each lasting 3 to 10 minutes, was informed by local needs assessment, including learner analysis, and literature on microlearning design (Corbeil et al., 2021; Jahnke et al., 2020; Lee et al., 2021; Major & Calandrino, 2018; Zhang & West, 2020), with faculty preferences for socially oriented, in-person learning significantly shaping the eventual design. Studying this case provided an important opportunity to address the limited research on how instructional design for microlearning relates to learner preferences and learning.

To study this case, a concurrent triangulation mixed methods design with identical sampling was used to answer this research question: How is employee learning impacted by microlearning design decisions made to address fundamental contradictions presented by learner preferences and workplace contexts? Following a review of relevant literature, this article summarizes the context and methods used for this research study, presents the results of quantitative and qualitative analysis, and situates those results in relation to previous and future research and practices involving microlearning.

2. Literature review

Relevant existing literature on microlearning includes guidance on its design, assertions about its social potential, varied approaches to the assessment of learning gained through microlearning, modest research on learner preferences, and imbalanced attention to the use of microlearning in varied workplace contexts.

2.1. Design of microlearning

While microlearning design was found to be the second-most researched topic in literature on microlearning published between 2005 and 2021, much of that literature focuses on technologies rather than principles, models, or theories of instructional design. Key themes have included the use of best practices and technology, interactivity and game-based learning, social media, virtual reality and augmented reality, reduction of cognitive load, and design for learning outcomes in varied subject areas (Sankaranarayanan et al., 2023). In some cases, information processing theory (DeGagne et al., 2019; Dolasinski & Reynolds, 2020), theoretical models of learners (Baumgartner, 2013), and specific types of learning, such as scenario-based learning (Zulueta & Panoy, 2022), have been offered to suggest effective approaches to designing microlearning. However, this literature often lacks a detailed presentation of the design approaches, principles, or models used. Some authors have offered principles for microlearning that lack a clear basis in broader instructional design literature, such as the importance of format, focus, autonomy, structure, and simple access (Díaz Redondo et al., 2021). Others have noted how the rise of constructivism and the focus on microcontent have challenged traditional instructional design models, with Kerres (2007) bluntly asking “What happens to instructional design if we move below the unit of a lesson?” (p. 99).

Despite these trends, several authors of previous research and practitioner literature on microlearning have highlighted the importance of approaching microlearning through sound instructional design practices. As several scholars have stressed, it is essential to approach microlearning through purposeful design rather than simply dividing up content into small pieces (Corbeil et al., 2021; Zhang & West, 2020). This includes critical steps such as needs assessment and knowing the audience (Dolasinski & Reynolds, 2020; Hogle, 2021; Hutaaruk et al., 2022; Margol, 2017). Other key design steps include writing behavior-based learning objectives that articulate isolated skills suitable to the scale of microlearning (Margol, 2017) and choosing suitable types of content (e.g., text, video, infographic) based on the skills to be developed and when they would be applied (Major & Calandrino, 2018; Margol, 2017). Several scholars have stressed the thoughtful application of Gagne’s events of instruction within microlearning’s durational constraints through emphasis on relevance, engagement, application, practice and application of content, and feedback, including applicability to mobile microlearning (Jahnke et al., 2020; Lee et al., 2021). Other design elements stressed for incorporation in microlearning have included activation of prior knowledge and contextualizing skills or problems “in real situations connected to learners’ jobs and careers so that they can immediately apply the learning” (Zhang & West, 2020 p. 316). Regarding the development of microlearning designs, practitioner literature echoes research-based literature in stressing the importance of exploring non-text elements to create time-efficient learning opportunities and including concise assessments of learning (Arshavskiy, 2020; Margol, 2017).

2.2. Social potential of microlearning

Social connectedness has been cited as a driver of microlearning (Torgerson, 2021) and social media has often been proposed as a good partner for microlearning (Grevtseva et al., 2017; Kohnke, 2021; Tennyson & Smallheer, 2021). That partnership can range from distribution of microlearning videos through social media to the fostering of deeper learning and a sense of community among learners through digital tools that support collaborative microlearning (Kohnke, 2021; Palmon et al., 2021). Social media and social networks offer both benefits and challenges for microlearning (Heydari et al., 2019). For example, Palmon et al. (2021) stressed the value of social media (e.g., Twitter) for distributing medical education microlearning videos because it can overcome scheduling barriers and other challenges for reaching learners. In preparing teachers, digital tools can enable peer feedback on teaching plans shared within social networks (Kelleci et al., 2018). Social learning, peer learning, and peer feedback can be fostered by incorporating elements such as chat, online discussions, blogs, and practice exercises (Kohnke, 2021; Margol, 2017).

2.3. Assessment of learning in microlearning

All levels of Kirkpatrick's model of training evaluation can be applied to microlearning (De Gagne et al., 2019; Fennelly-Atkinson & Dyer, 2021). Level 2 evaluation, or assessment of learning, can be conducted through quizzes, tasks, self-assessments, and behavioral analysis; learning analytics have also been recommended and used to study microlearning (Fennelly-Atkinson & Dyer, 2021; Gross et al., 2019; Javorcik & Polasek, 2018). While some have suggested that social media can be used for assessment (Fennelly-Atkinson & Dyer, 2021; Kohnke, 2021), others have noted that social media can hinder assessment, specifically efforts to measure the educational benefits of microlearning videos distributed through Twitter (Palmon et al., 2021).

Despite these options for assessment, published research provides an imbalanced picture of microlearning's effectiveness. Publications on microlearning often do not attempt to measure learning directly, but rather learner response, preference, comfort, or confidence (Hegerius et al., 2020; Hesse et al., 2019; Heydari et al., 2019; Tennyson & Smallheer, 2021). Moreover, in their scoping review of literature on the effectiveness of microlearning, Taylor and Hung (2022) found a preponderance of research on the effects of microlearning in the medical and healthcare fields, with studies often measuring task performance proficiency and knowledge acquisition.

2.4. Learner preferences and microlearning

Efforts to note or address learner preferences involving microlearning have included research studies justifying the use of microlearning to address learner preferences among formats (e.g., elearning vs. microlearning) (Heydari et al., 2019; Javorcik & Polasek, 2018) and examining their preferences in interacting with videos in microlearning (Sung et al., 2023). However, there is limited evidence on how instructional design decisions made when developing microlearning in response to learner preference may impact learning. This article fills this void by addressing the intersection of instructional design, learner preferences, and assessment of learning within the microlearning format.

2.5. Workplace contexts

At the same time, this study addresses the disciplinary imbalance of empirical studies of microlearning to date. While microlearning has been promoted and adopted across many industries, scholarly literature reflects less industry diversity, with health professions and education being heavily represented. Hesse's et al. (2019) examination of microlearning in dairy farming illustrates a noteworthy exception to this imbalance. Taylor and Hung noted "an urgent need for more non-medical/healthcare empirical studies of microlearning to help enrich our understanding of this instructional approach," based on the unique nature of domain-specific knowledge, reasoning skills, and culture and the risk that studies of "a limited number of contexts may skew our understanding of its general effects as well as context-dependent effects on student learning" (Taylor & Hung, 2022, p. 27). This study addresses this gap by examining microlearning used to strengthen knowledge and skills in the domain of teaching in a non-medical higher education workplace context.

3. Context and methods

3.1. Context and participants

The microlearning faculty development program was designed, developed, and implemented at a small comprehensive university in the urban southeastern United States with approximately 130 full-time faculty and 170 part-time faculty. At this university, 32% of students are minority and 7% are international students; 15.3% of faculty are minority and 0.3% are international. Eleven faculty members participated in the research study and completed the faculty development program (Table 1 below). Of these, 9 identified as female, 2 identified as male, 1 identified as Asian, and 10 identified as white, 1 of whom also identified as Hispanic. Participants ranged in age from 28 to 70 years with a mean of 50 years. The participants included 3 part-time and 8 full-time faculty members. The author and study participants had previously interacted as colleagues through faculty orientations, workshops, and faculty development consultation services.

The microlearning program was run as self-paced learning during one month with program completion required for a modest stipend compensating faculty for their time beyond their standard contract period. The research

protocol was previously submitted to the university's Institutional Review Board (IRB), which determined that the project satisfied the federal regulatory criteria for exemption from further IRB review. Study participants represented a convenience sample of the university's faculty. After all faculty were invited to express interest in the program, 22 faculty entered the elearning app containing the program and consent form. Of those, 11 consented to participate in the research study and completed the program. Identical sampling was used with the same set of research participants providing both quantitative data and qualitative data.

Table 1. Participant demographics

Characteristic	Response	Number
Gender	Female	9
	Male	2
Race and ethnicity	White	10
	Asian	1
	Hispanic	1 (also identified as white)
Age	20–29	1
	30–39	1
	40–49	5
	50–59	2
	60–69	1
	70–79	1
Time base	Full-time	8
	Part-time	3

The author conducted the needs assessment, designed and developed the microlearning program, developed the data collection tools as integral parts of the program, and analyzed the data. The author's experience in the participants' organizational environment is consistent with Lee et al.'s assertion that "It is critical that researchers embed themselves into the learners' contexts and deeply understand the relationship among the media (digital technology) they use, the learning materials they engage with, and their real learning situations. They will then be able to develop a better learning solution" (Lee et al., 2021, p. 886).

3.2. Microlearning lessons

The self-paced program included 13 microlearning lessons delivered through Canvas, including its mobile app; this choice of technology (hereafter called "elearning app") enabled participants to complete lessons on a computer, tablet, or phone. Individual lessons delivered content about 5 to 10 minutes in length, except for the shorter concluding lesson. Needs assessment, literature review, and consideration of the local context and learners' preferences informed the program's design. First, survey responses from academic program leaders and a random sample of syllabi were analyzed to determine the need for developing faculty skills that support the success of a diverse student population. Skills identified for development related to assessments of learning, learning activities, and instructional climate and prompted a cognitivist approach to most elements of the program. Backwards design was identified as a useful framework for sequencing lessons; a short lesson was included to elucidate backwards design (Table 2 below).

Second, like other microlearning solutions that respond to challenges in workplace contexts (Lee et al., 2021; Palmon et al., 2021), microlearning was adopted to address common challenges in faculty development for inclusive teaching as noted in relevant literature. Faculty time, workload, scheduling conflicts, and program expenses have been reported as common obstacles to engaging faculty in such programming and scaling programming to reach all faculty at an institution (Guilbaud et al., 2021; Hsiao et al., 2019; Hudson, 2020; Wynants & Dennis, 2017). Microlearning is efficient and responsive to the scarcity of time and allows learners to complete learning experiences faster than other formats, such as regular elearning (Javorcik & Polasek, 2018; Leong et al., 2021; Torgerson, 2021). Figure 1 illustrates how lesson content presentation was limited in scope and presented in a practical format, such as steps supporting learner application. Figures 2 and 3 illustrate the mixture of concise verbiage, images, and videos used in lesson content in the computer and phone interfaces.

Table 2. Design of microlearning lessons

Lesson and focus	Learning objective	Duration of content	Knowledge check	Discussion	Application activities	Self-assessment
0. Orientation to program and	-	10 minutes	-	-	-	-

app							
1. What does inclusive teaching mean?	Explain what is encompassed by the phrase “inclusive teaching.”	5 minutes	-	Required	-	-	
2. Evaluate one’s current teaching practices in relation to a diverse student population	Using the self-assessment tool, evaluate one’s current teaching practices to identify at least two major areas in which inclusive teaching techniques can be adopted to support all students.	10 minutes	-	-	Self-evaluation using Inclusive by Design worksheet	Yes	
3. Pillars of inclusive teaching	Identify three pillars of inclusive teaching and specific instructional techniques that illustrate each	10 minutes	Yes	Optional	-	-	
4. Using backward design to approach inclusive teaching	Explain the basic sequence of decision-making used in backward design, how it relates to the entire course preparation process, and how it impacts implementation of inclusive teaching techniques.	10 minutes	Yes	-	-	-	
5. Transparency in assessments through descriptive rubrics	Given models, create an analytical rubric that provides students specific, descriptive feedback on their work based on at least three criteria that are aligned with course or module learning objectives and the letter grading system.	5 minutes	Yes	-	Create an analytical rubric	Yes	
6. Increasing relevance and access through assessments that incorporate choice	Given models, construct an assessment of learning that gives students a choice between at least two questions or prompts and at least two submission formats while remaining consistent with learning objectives.	5 minutes	Yes	-	Create an assignment prompt that incorporates choice	Yes	
7. Synthesis of skills developed in previous two	Using models, create a rubric for an assessment of	5 minutes	-	-	Create an analytical rubric for	Yes	

lessons	learning that gives learners a choice of questions and a choice of submission formats, providing transparency about expectations and transparent feedback based on at least three criteria that are aligned with course or module learning objectives.					an assignment that incorporates choice	
8. Create inclusive learning experiences	Increase the inclusivity of learning experiences in one's courses.	10 minutes	-	Required	-	-	
9. Plan for inclusive learning activities through discussion	Using models and a job aid, plan for a class discussion so that a diversity of perspectives is expressed and all students' sense of belonging is maintained, by using at least two preparation techniques.	5 minutes	-	Optional	Create a plan for an inclusive discussion	Yes	
10. Moderate inclusive discussions as learning activities	Using models and a job aid, moderate a class discussion so that a diversity of perspectives is expressed and bias is interrupted, by using at least two facilitation techniques, and at least two techniques to interrupt bias and micro-aggressions.	5 minutes	-	Optional	Respond to a scenario	Yes	
11. Interact with students using inclusive written and oral communication	Given models and a job aid, create more inclusive course documents exhibiting at least 5 techniques in the syllabus checklist.	5 minutes	-	-	Create or revise a syllabus	Yes	
12. Interact with students using inclusive written and oral communication	Given models and a job aid, provide supportive, constructive written or oral feedback on student work, exhibiting at least 5 techniques in the feedback checklist.	5 minutes	-	Optional	Respond to a scenario	Yes	
13. Final Self-Evaluation and Final Reflection	Using the self-assessment tool, evaluate one's	3 minutes	-	-	Self-evaluation using	Yes	

current teaching practices to identify at least two major areas in which inclusive teaching techniques can be adopted to support all students.	Inclusive by Design worksheet
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Figure 1. Screenshot of teacher-designer view of items in Lesson 6

Lesson content

Knowledge check

Application activity

Pre-lesson items for data collection

Post-lesson items for data collection

Figure 2. Screenshot of part of a content page in Lesson 6 in the computer interface

Choice in Submission Format

The first type of choice - choice in submission format - can allow us to increase access, the A in the TAB framework.

You can choose to read or watch why and how to give students a choice in submission format. Then scroll down and continue by reading the section titled "Not to Be Confused with..." through the end of this page.

Watch about Choice in Submission Format

The first video summarizes how giving a choice in submission format relates to the Universal Design for Learning framework. The second video offers a unique anecdote suggesting how such assignments can have a lasting impact on learners.

UDL A Action expression for Expression & Communication

Use multiple media for communication. Watch later Share

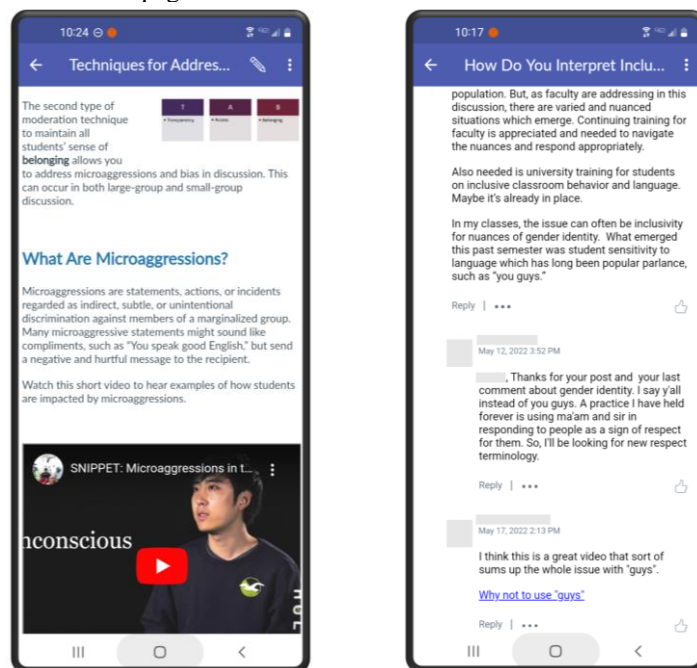
Watch on YouTube

UDL A LACOE. (n.d.) UDL A Action expression. [Video]. YouTube. <https://youtu.be/6TupyBVkR7w>

Third, learner preferences contradicting the time-constrained organizational context shaped the design of some microlearning lessons. Faculty at the university preferred in-person learning, synchronous learning, discussion-based formats, peer learning, and learning from faculty rather than staff or administrators. So even though faculty had insufficient time and often made limited use of these preferred formats, their preferences risked dissatisfaction with the cognitivist microlearning format identified as appropriate based on needs assessment. To address these challenges, six required and optional asynchronous discussions were added to the program design to support peer learning (Table 2 and Figure 3). Discussions were incorporated in ways that generated a wide range of lesson designs, including lessons with an artifact- or scenario-based application activity, a discussion,

both, or, neither. In lesson 8, learner choice among several specific skills was incorporated to address the varied prior knowledge of university faculty and support them as adult learners.

Figure 3. Screenshots of a content page in Lesson 10 and redacted discussion from Lesson 1 on the phone app



3.3. Data collection and analysis

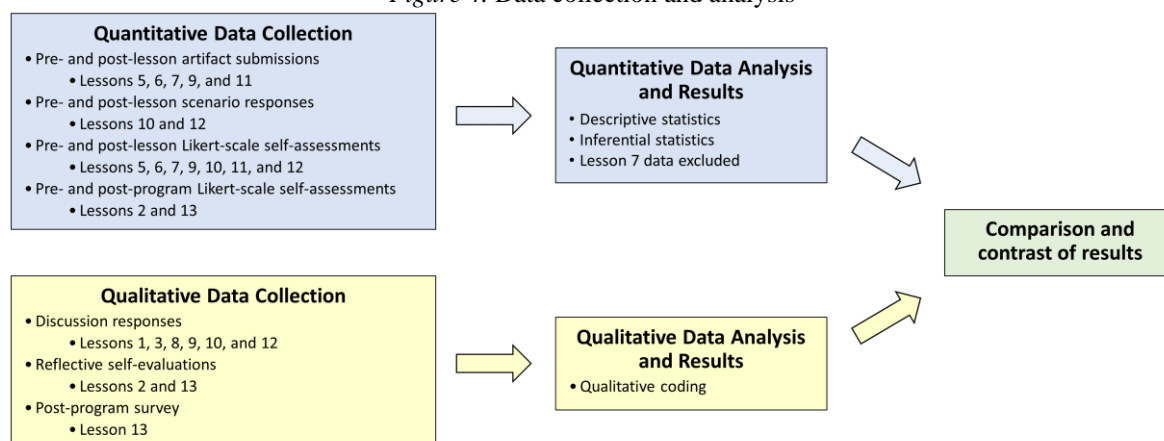
This study used a concurrent triangulation mixed methods design to answer this research question: How is employee learning impacted by microlearning design decisions made to address fundamental contradictions presented by learner preferences and workplace contexts? Both quantitative and qualitative data were collected through the elearning app and analyzed to strengthen validity and address limitations of each data type; data sources are listed in the 3 rightmost columns in Table 2. Prerequisites were set on content in the elearning app to ensure completion of learning assessments and activities used to collect data (Figure 1).

Distinct types of quantitative data were collected to measure the impact of individual lessons' design and the entire program on participants' learning. First, for the purposes of this study, seven lessons gathered both pre- and post-lesson data through the quantitative scoring of submitted artifacts and responses to scenarios that were included as application activities (see Application Activities column in Table 2, Figure 1, and Figure 4). Rubrics and checklists for this scoring were created during the program's design and development prior to participant recruitment; analytical rubrics were created to score artifacts submitted in lessons 5, 6, 7, 9, and 11, while checklists were used to score responses to scenarios in lessons 10 and 12. Second, nine lessons included a pre- and post-lesson self-assessment consisting of a Likert-scale question. At the beginning and end of seven lessons, the question asked participants to rate their ability level on the skill addressed in the lesson (i.e., 0 = no ability, 1 = basic ability, 2 = moderate ability, 3 = advanced ability, 4 = expert ability). In two lessons at the beginning and end of the program, the question asked participants to use the same scale to rate their ability to evaluate the inclusiveness of their teaching (Figure 4). Descriptive and inferential statistical analyses of pre- and post-lesson scores on artifacts, scenarios, and Likert-scale self-assessments were conducted to measure participant learning in individual lessons; both the paired sample *t*-test and Wilcoxon signed-rank test were used. Due to lesson 7 being unpublished at the beginning of the month, only 3 study participants completed it and data from this lesson were excluded from the analyses.

Qualitative data were collected to gauge participant learning, learning experiences, and perceptions of the design. Qualitative data were collected through participants' responses to open-ended questions in asynchronous discussions, reflective self-evaluations (Application Activities, Table 2), and a post-program survey. Responses were required for two discussions and optional for the other four (Discussion, Table 2). Inductive qualitative coding began with exploratory, eclectic coding and constant comparison using descriptive, in vivo, process, and concept codes in Taguette (Saldaña, 2021). Codes were compared with lesson design and analytical memos and categorization of codes were used to identify key patterns in the data. Results of the quantitative and qualitative

analyses were compared for corroboration, discordance, elaboration, and clarification (Creswell & Clark, 2007; Greene, 2007).

Figure 4. Data collection and analysis



4. Results

The results of quantitative and qualitative data analyses clarify how employee learning was impacted by microlearning design decisions made to address fundamental contradictions presented by learner preferences and the workplace context. While quantitative data analysis revealed significant participant learning aligned with lesson objectives, qualitative analysis revealed that learners also engaged in learning beyond those learning objectives due to design decisions made to accommodate learner preferences for discussion-based learning and learning from peers.

4.1. Quantitative results

Quantitative data analysis revealed increases in participants' mean post-lesson scores in two ways. First, participants' self-assessment scores increased in individual microlearning lessons and the entire program. Based on the difference between the means of the pre-lesson and post-lesson self-assessments, the participant group reported skill development in all lessons (Table 3 below). The greatest increases in self-assessment score means (0.9 to 1.0) occurred in lessons 5, 6, and 11, which focused on increasing transparency in instructor expectations by using descriptive analytical rubrics, assessments that give students choice among multiple prompts and multiple submission formats, and inclusive communication in course documents such as syllabi. Increases in self-assessment score means (0.5 to 0.7) also occurred in lessons 9, 10, and 12, which addressed planning for and moderating inclusive discussions to address microaggressions and bias and providing inclusive feedback on student work. A similar overall increase in self-assessment score means (0.7) resulted from the self-assessment question in lessons 2 and 13. Second, post-lesson scenario response and artifact score means increased when compared with pre-lesson means. These differences evidence skill development in all lessons (Table 3).

Table 3. Pre- and post-lesson self-assessment, artifact, and scenario score means

Lesson and focus		Self-assessment means			Artifact and scenario means		
		Pre	Post	Difference	Pre	Post	Difference
2	Self-evaluation of inclusive teaching practices	1.9	-	-	-	-	-
5	Transparency through descriptive rubrics	1.55	2.46	+0.91	3.23	9.77	+6.54
6	Assessments that incorporate choice	1.36	2.36	+1.0	2.27	5.18	+2.91
9	Plan for inclusive discussions	1.82	2.46	+0.64	0.82	5.64	+4.82
10	Moderate inclusive discussions	2.0	2.55	+0.55	5.18	5.27	+0.09
11	Inclusive communication in course documents	1.64	2.55	+0.91	1.82	5.27	+3.45
12	Inclusive feedback	1.91	2.46	+0.55	4.18	7.09	+2.91
13	Self-evaluation of inclusive teaching practices	-	2.64	+0.73	-	-	-

Due to the small sample size, a Shapiro–Wilk test was performed, and it showed that the distribution of artifact scores in lessons 5, 6, 9, and 11 did not depart significantly from normality, while the distribution of scenario scores from lessons 10 and 12 departed significantly from normality ($W = 0.72$, $p < 0.001$; and $W = 0.81$, $p =$

0.013, respectively). Based on this outcome, a parametric test (paired sample *t*-test) was used for scores from lessons 5, 6, 9, and 11 and a non-parametric test (Wilcoxon signed-rank test) was used for scores from lessons 10 and 12.

The participant group's scores on artifacts and scenarios submitted after lessons 5, 6, 9, and 11 were higher than those submitted before each lesson. Results of a paired sample *t*-test indicate that these improvements were statistically significant in all 4 lessons (Table 4). These differences were found to have a medium effect size (0.624 to 0.725). A pair of pre- and post-lesson artifacts created by the same participant in lesson 5 illustrates the differences in artifacts that generated these statically significant score increases (Appendix).

Table 4. Pre- and post-lesson artifact scores

Test scores	Mean	Standard deviation	Mean difference	<i>t</i> -test	<i>df</i>	<i>p</i> value
Lesson 5 Transparency through descriptive rubrics						
Pre-lesson	3.227	3.235	6.545	-6.409	10	< .001
Post-lesson	9.773	2.114				
Lesson 6 Assessments that incorporate choice						
Pre-lesson	2.273	1.191	2.909	-6.672	10	< .001
Post-lesson	5.182	0.982				
Lesson 9 Plan for inclusive discussions						
Pre-lesson	0.818	0.603	4.818	-5.663	10	< .001
Post-lesson	5.636	2.767				
Lesson 11 Inclusive communication in course documents						
Pre-lesson	1.818	0.982	3.455	-5.300	10	< .001
Post-lesson	5.273	1.679				

Scenario scores revealed that participants also demonstrated skill development in lesson 12 on providing inclusive feedback on students' work, but not in lesson 10 on moderating inclusive discussions. A Wilcoxon signed-rank test indicated that lesson 12 significantly improved participants' ability to provide inclusive feedback on student work (*Mdn* = 7) compared to their ability before the lesson (*Mdn* = 4), $z = -2.666$, $p = 0.008$ (Table 5).

Table 5. Pre- and post-lesson scenario scores

Test scores	Median	Standard deviation	Median difference	<i>z</i>	<i>df</i>	<i>p</i> value
Lesson 10 Moderate inclusive discussions						
Pre-lesson	5	0.874	0	-0.535	10	0.773
Post-lesson	5	0.647				
Lesson 12 Inclusive feedback						
Pre-lesson	4	1.250	3	-2.666	10	0.008
Post-lesson	7	1.814				

4.2. Qualitative results

Qualitative coding revealed how including discussions in microlearning lessons to accommodate faculty preferences for peer learning supported and evidenced participants' learning. Discussions did so by providing outlets for learning that went beyond the learning objectives identified through needs assessment, by prompting participants to make connections between ideas and experiences, and by providing a forum for participants to build on one another's ideas (see Table 6).

Table 6. Themes, categories, and sample codes in analysis of discussion responses

Theme	Category	Sample codes
Learning beyond the learning objectives	Reflection	Reevaluating past actions
		Questioning past actions
	Articulation of struggle and conflict	Addressing a struggle
		Expressing a contradiction
Making connections	Source-lesson connection	Connection to a text
		Connection to an image
	Experience-lesson connection	Connection to daily experience

Building on one another's ideas	Contributing support	Connection to teaching
		Adding evidence
	Extending peers' contributions	Posing a new question
		Offering a new interpretation
		Pushing exchange to a new level

4.2.1. Learning beyond the learning objectives

First, participants' discussion activities included reflection, questioning, and articulation of struggles and conflict that often went beyond the target learning objective. In several lessons, participants reflected on past teaching experiences and shared examples of ways they had furthered or hindered inclusivity. One participant reflected on and evaluated the limits of their previous understanding of inclusive teaching: "I think my focus though has been more with providing accommodations for students with learning differences. While in the back of my mind I was aware of additional barriers (working schedules and different cultures)." Some participants questioned and evaluated their past practices or expectations regarding inclusive teaching. For example, in lesson 1, a participant reflected on her response to a student who indicated having anxiety about public speaking and wanted to email her statements instead of contributing to a live discussion. As the participant explained,

I said no, because an e-mail after the fact is fundamentally different, but instead I offered everyone in the class an option to participate via a live chat projected on the board. She still declined, and I gave zeros on those discussions. I may get criticism here for not being inclusive, and I don't know if I handled it the right way, but in my estimation I couldn't give as much as she wanted and she wouldn't accept anything else.

In lessons 1 and 3, several participants articulated struggles and conflicts, such as conflicts between providing students flexibility and maintaining academic standards, between aspiring to address all students' needs and feeling overwhelmed due to limited time and resources, and between wanting to cultivate a supportive tone when communicating with students and fearing students' perception of that tone as an invitation to take advantage of instructor flexibility in pursuit of reduced standards or accountability.

Through recurring reflection, questioning, and articulation of conflict, participants' discussion contributions provided evidence of learning that went beyond the learning objectives targeted based on needs assessment. Compared with the learning objectives shown in Table 2, several of these "learner-added" learning objectives were at higher cognitive levels (e.g., analyze) than the lesson objective (e.g., identify, explain). Examples of added learning objectives demonstrated by participants' discussion contributions included:

- Lesson 1: Analyze factors that have contributed to your disuse of inclusive teaching techniques
- Lesson 3: Analyze factors that can hinder implementation of teaching techniques that support the pillars of inclusive teaching
- Lesson 3: Propose solutions to risks and factors that hinder implementation of inclusive teaching techniques

Some participants' discussion contributions in lesson 3 illustrated analysis of factors hindering implementation of teaching techniques that support pillars of inclusive teaching, which were defined in the program as transparency, access, and belonging. Factors identified by participants included limited time, limited familiarity with various barriers faced by students, and the paradox of increasing barriers by reducing barriers. For example, one participant noted that if a \$100 textbook were replaced with a free, open-source textbook, "students lose the electronic homework system which has built-in help tools; students like it, especially in online sections. For us, lowering barriers in one way comes at a cost of raising barriers in a different way."

In lesson 9, some participants engaged in deeper, critical reflection by evaluating past teaching techniques, experiences, and assumptions rather than simply planning for an inclusive class discussion by using specific preparation techniques as called for by the lesson's learning objective. Participants initially articulated their struggles in making a discussion inclusive when some students hold views that are not inclusive. After initially locating the problem with students, participants shifted their attention to their own impact on these discussions in their classes. They ultimately developed their evaluative reflections to the point that one participant, in a moment of deep insight, acknowledged that faculty who considered their attitudes and approaches to be inclusive could be framing topics in a biased and exclusive way that did not create the space for students with more conservative views to contribute.

4.2.2. Making connections

A second important way that discussions shaped and evidenced participants' learning was through their connecting ideas from varied sources, such as other readings, and from past experiences to achieve deeper learning. Participants made such connections in several lessons, including lesson 8, which focused on inclusive learning activities. Participants synthesized concepts from the lesson with observations and learning from daily experiences and previous professional development activities. For example, one participant connected content on digitally accessible materials to a recent email that she realized did not provide information in an accessible way. Another participant made a connection with the lesson's suggestion of creating a glossary to clarify language and symbols, a suggestion drawn from the principle of providing multiple means of representation in the Universal Design for Learning framework. The participant connected this concept from the lesson to a collaborative file creation activity she participated in during a previous professional development program. Synthesizing these ideas and experiences, she proposed having students collaboratively create the glossary in a cloud-based file. In this way, discussions evidenced and supported participants' synthesis of knowledge from multiple sources and experiences in ways more aligned with a constructivist view of learning than the cognitivist view that had driven much of the program's needs assessment-based design.

4.2.3. Building on one another's ideas

A third important element of learning fostered and illustrated by participants' discussion contributions was building on one another's ideas. While in some cases this involved contributing new evidence, in others this involved adding new interpretations. In Lesson 3, one participant (A) noted that transparency was more difficult to achieve than access or belonging because "How do we know what we don't know? I feel I'm always missing something, leaving something out. What are my unspoken assumptions?" Another participant (B) addressed and built on this observation by introducing metaphors related to time and space:

How do we take our minds back to the state of a student, a time when we didn't know this material either? Material that, by now, we know well? How do we jump down into the hole with the student and show how to climb out?

Elaborating on the metaphor of discovery through space, participant B offered a possible solution to the challenge faculty face in identifying what is unknown to students:

The idea of descriptive rubrics that communicate expectations sounds interesting. When students ask for a detailed rubric, I often read that as a signal that they're looking for a list of boxes to check. But maybe they're just looking for a map in unknown territory. Perhaps there's a way to create a rubric that encourages exploration of the territory, rather than just a list of mileages and highway numbers.

Participant A then built on this map metaphor to articulate how she could help students understand metaphor by using a rubric:

Yes, "a map in unknown territory." That's one of the metaphors our textbook uses for discussing the transmission and transformation of folklore around the globe. Perhaps I could flip that and also use the map as a way of explaining the meaning of metaphor to some of [the] students with the development of a rubric that encourages viewing an assignment as a journey—a quest if you will.

A third and fourth participant (C and D) then noted how considering this discussion of metaphor helped them address their prior perception of rubrics as "boxes for students to check," a perception that they came to realize had been preventing them from using rubrics effectively. Participant C elaborated on the metaphor by asking how faculty could "provide the students a map/travel guide instead of a GPS?" Such exchanges illustrate how design decisions, particularly the inclusion of discussions, enabled participants to pursue learning beyond that conceived in the original learning objectives, which were largely based on a cognitivist view of learning, and engage in learning more aligned with a constructivist view.

4.3. Integration of qualitative and quantitative data

Qualitative post-program survey data can help interpret some of these quantitative results, including explaining unexpected results and clarifying learners' experiences when completing individual lessons. While quantitative analysis showed that significant learning occurred in lesson 5 focused on rubrics, qualitative analysis of post-

program survey data revealed that six participants identified this as the hardest lesson to complete. When explaining this, participants noted their dislike of the content, resistance to or questioning of the content due to colleagues' views, lack of confidence, and lack of prior experience. Participants' explanations point to a possible design flaw of not sufficiently addressing learners' preexisting opinions and attitudes when designing individual lessons. Survey data also help explain the lack of significant score increase for scenarios in lesson 10 on facilitating inclusive discussions. While many participants exhibited strong skills in their pre-lesson scenario responses and used similar techniques in their post-lesson scenario responses, one participant identified it as a confusing lesson, citing cognitive overload and the fact that the "topic made it harder to have a concrete guideline." The cognitive overload was likely fueled by the lesson's reliance, unlike other lessons, on externally created pre-existing resources rather than information distilled from them into one elearning app page tightly aligned with the lesson's focus. In addition, the topic required context-dependent use of skills, making it challenging to articulate guidelines with the clarity possible for other topics.

Conversely, quantitative data helps clarify the possible impact of design decisions on participants' learning. The addition of asynchronous discussions revealed that some participants' learning extended beyond the planned lesson learning objectives; a possible consequence was that their attention was diverted from those objectives. As seen in lesson 9, however, the participant group demonstrated strong skill development based on comparison of scores on pre- and post-lesson artifacts even as some participants also engaged in more complex learning as evidenced in their asynchronous discussion. The lessons that contained both artifacts or scenarios assessing participants' progress on lesson learning objectives and asynchronous discussions that could have prompted and documented learning beyond those learning objectives—lessons 9, 10, and 12—generated varied score increases on pre- and post-lesson artifact and scenario scores, ranging from negligible to statistically significant increases. This suggests that other factors—such as using decontextualized, short scenarios to assess participants' learning—may have contributed to those varied results.

5. Discussion

Consideration of both quantitative and qualitative results helps answer the fundamental question: How is employee learning impacted by microlearning design decisions made to address fundamental contradictions presented by learner preferences and workplace contexts? Based on these results, the combination of adherence to fundamental instructional design principles resulting in decisions to use a primarily cognitivist framework and accommodation of learner preferences by providing complementary outlets for topical social interaction enabled learners to achieve the intended learning objectives identified through needs assessment while also allowing them to achieve higher order learning in ways consistent with social constructivism. Insufficiently focused learning materials and insufficiently realistic scenarios, rather the diversion of attention to social interaction, appear to have contributed to some lessons producing less learning than others. These results also add important findings to literature on microlearning, highlight several important design considerations, and support specific design recommendations.

5.1. Social potential of microlearning

First, this study enriches our understanding of the social potential of microlearning and reinforces its importance. While several previous studies have stressed the value of social media for distributing microlearning, particularly in video format, this study has clarified how microlearning can support collaborative, socially constructed learning as urged by Kohnke (2021) and Göschlberger (2017). Participants' questioning and building on one another's ideas to generate new knowledge is best understood from the perspective of social constructivism and occurred despite a design shaped primarily by a cognitivist perspective. This suggests the value of intentionally designing microlearning to support collaboration and socially constructed knowledge where appropriate based on needs assessment.

5.2. Learners' preferences, prior knowledge, beliefs, and attitudes

This study confirms the importance of conducting needs assessment when designing learning (Wang et al., 2010). It demonstrates the impacts of using needs assessment not simply to inform the use of microlearning instead of a more traditional delivery format, but rather to inform the design of microlearning lessons themselves. Learner analysis and analysis of the learning context, including the organizational workplace setting, are important for informing a microlearning design that accounts for and is responsive to learner characteristics

and preferences as well as contextual factors that can constrain or enable learning. Reflecting learning design decisions based on learner and context analysis, discussion opportunities not only supported deep learning but also elicited positive participant feedback in the post-program survey. In addition to participants' citing the microlearning's useful, well-organized content being "packed" into a concise and schedule-friendly format, three participants specifically cited opportunities for peer input or discussion as factors that would prompt them to use microlearning again. This feedback is even more significant given the strong faculty preference for in-person learning before the COVID-19 pandemic and ongoing interest in returning to in-person learning after its peak.

Moreover, findings from qualitative analysis suggest that an important distinction be made between learners' willingness to engage in or "adopt" microlearning and their adoption of the content and behavioral changes targeted through microlearning (Puah et al., 2022). As illustrated through participants' explanations of how their own beliefs and peers' beliefs impacted their reactions to content of the microlearning program, learners' integration of new knowledge and willingness to adopt new skills are impacted by prior knowledge and attitudes about the subject matter. Despite design alterations made to accommodate faculty preference for social learning opportunities in the structure of microlearning program as a whole, post-program survey responses clarified that more attention was needed to learners' possible attitudes, opinions, and beliefs about specific content. This suggests the importance of approaching microlearning lesson design with attention to ways that learners can incorporate new and prior knowledge, reflect on prior knowledge, and revise their own individual understandings (Simons & Crawford, 2021).

5.3. Types of learning objectives

Results indicate that microlearning promoted participants' learning at the cognitive levels of creation, analysis, and application, reflecting both planned learning objectives and learners' engagement in deeper learning. This contrasts with some prominent guidance on microlearning. Microlearning has been identified as good for "teaching dense, fact-based content" (Hogle, 2021, p. 143), and those who have focused on mobile microlearning have deemed it suitable for lower-level cognitive learning objectives and topics "that are easy to learn, and that have a correct answer available" (Jahnke et al., 2020, p. 611). Microlearning has been used extensively for procedural learning objectives, such as surgical technique (Hesse et al., 2019; Ichijui et al., 2022; Palmon, 2021; Taylor & Hung, 2022; Wakam et al., 2022), while being deemed inappropriate for complex processes, complex skills, or activities that require sequencing and balancing many behaviors (Fennelly-Atkinson & Dyer, 2021; Margol, 2017). Despite this emphasis in previous literature, the present study suggests that microlearning, including microlearning that can be used on mobile devices, can support learners' achievement of higher cognitive-level learning objectives and application of complex problem-solving skills. This mixed methods study has provided more robust and detailed findings that support Göschlberger's (2017) assertions, based on Baumgartner's (2013) three-level model of learning, that social interaction in microlearning can help learners move from lower-level cognitive objectives to higher-level cognitive objectives, including critical analysis and reflection.

5.4. Assessment design in microlearning design

The interplay of design decisions and evidence of participant learning also offers important insights for assessing learning in microlearning. The inclusion of varied ways for participants to demonstrate their learning revealed the potential limitations of certain types of assessments in microlearning. Closed-ended questions and scenarios with limited response options may offer concise ways of assessing learning within durational parameters commonly associated with microlearning (Arshavskiy, 2020; Margol, 2017). They may also offer the convenience of quickly determining scores. However, they may not reveal the breadth and depth of learning supported by a microlearning program. An irony of the design process that shaped the microlearning program in this study is that the discussions that revealed participants' deeper learning would not have been included if not for concern about faculty frustration and disappointment with a program that lacked opportunities for social interaction. The program's original conception emphasized short self-assessment questions and realistic work samples that could measure participants' progress on lesson learning objectives. However, in some lessons, it was only because of design changes to accommodate learner preferences that deeper learning was evidenced. This suggests that designers consider providing varied ways for learners to demonstrate their learning; even if some activities or assessments are not required for program completion, they can still provide valuable insights about the potential of a microlearning program to support development of skills or knowledge that the designer may not have anticipated. Thus, microlearning design should involve careful attention to the design of assessments of learning in addition to the design of content.

6. Limitations and future research

This study has several limitations, including the small number of participants, author's fulfillment of multiple roles, and possibility of self-selection bias. Participants may have had greater appreciation for or openness to inclusive teaching and may not have been fully representative of the university's faculty. As participants came from only one type of university, results may not be representative of higher education faculty more generally, such as faculty who work in research universities or have primarily graduate-level teaching responsibilities.

Despite these limitations, this study suggests important directions for future research related to the pedagogical and evaluation dimensions of Khan's elearning framework as adapted for microlearning (Corbeil et al., 2021). First, the social component of microlearning should be examined further with respect to its impact on learning. In particular, extending the work of Göschlberger (2017), further research should be conducted to test how social interaction in microlearning may assist learners in moving between Baumgartner's (2013) three levels of learning: absorption, acquisition, and construction of knowledge, which Baumgartner relates to behaviorism, cognitivism, and constructivism, respectively. Second, more research should be conducted to clarify the types of learning objectives that can be effectively addressed through microlearning, and under what design, delivery, and social conditions. While existing frameworks articulate several dimensions of microlearning, learning objectives have been overlooked in favor of dimensions such as target group, learner's role and participation, time spent, and content type, creation, aggregation, and retrieval (Buchem & Hamelmann, 2010; De Gagne et al., 2019).

Finally, future research may address challenges of assessing learning, particularly learning of complex skills, in microlearning. While assessment of work samples was incorporated in this study, it may have increased the time some participants spent on program activities beyond common durational definitions of microlearning. Assessment of learning (as opposed to learner perceptions and reaction) may impact the nature, duration, and experience of microlearning (Fennelly-Atkinson & Dyer, 2021). Conversely, assessing learning from microlearning may be challenging when that learning continues through application activities involving real workplace tasks. For these reasons, additional mixed methods research may be especially helpful in providing further insight on the assessment of learning through microlearning, the social component of microlearning, and their relationship to principles of instructional design, including suitable learning objectives.

7. Conclusion

This examination of how microlearning can be designed to promote learning in challenging workplace circumstances while also responding to learners' contradictory preferences highlights how designing and assessing microlearning are just as complex as for other formats of learning. Fundamentally, delivering successful microlearning for learners who do not want it hinges on basic principles of instructional design, including needs assessment, learner analysis, and adaptation to learner and contextual characteristics. In the case studied, the combination of adherence to fundamental instructional design principles resulting in decisions to use a primarily cognitivist framework and accommodation of learner preferences by providing complementary outlets for topical social interaction enabled learners to achieve the intended learning objectives identified through needs assessment while also allowing them to achieve higher order learning in ways consistent with social constructivism. This combination of approaches also resulted in positive learner feedback that both stressed the useful, well-organized content being "packed" into a concise and schedule-friendly format and noted the opportunities for peer input or discussion as factors that would prompt them to use microlearning again. This study suggests the value of intentionally designing microlearning to support collaboration and socially constructed knowledge where appropriate based on needs assessment.

Studying this case has addressed key gaps in the literature on microlearning. First, it has contributed a close study of the impact of design decisions on learning, learner experience, and assessment of learning in a way that illustrates the continued relevance of instructional design principles for microlearning amid literature that often emphasizes relevant technologies and has questioned the value of instructional design. Second, it has responded to the call for more research on microlearning in varied non-medical contexts.

This case study also highlighted several more specific takeaways relevant to existing and future research on microlearning. This study confirmed the importance of conducting needs assessment when designing learning (Wang et al., 2010) and not simply to inform whether microlearning is used, but rather how it is used. It also exposed the importance of attending to learners' possible attitudes, opinions, and beliefs about specific content and approaching microlearning lesson design with attention to ways that learners can incorporate new and prior knowledge, reflect on prior knowledge, and revise their own individual understandings (Simons & Crawford,

2021). It suggests that microlearning, including microlearning that can be used on mobile devices, can support learners' achievement of higher cognitive-level learning objectives and application of complex problem-solving skills. It supports Göschlberger's (2017) assertions, based on Baumgartner's (2013) three-level model of learning, that social interaction in microlearning can help learners move from lower-level cognitive objectives to higher-level cognitive objectives, including critical analysis and reflection. At the same time, this study called attention to the possibility that concise assessments of learning well suited to microlearning's chronological scale (Arshavskiy, 2020; Margol, 2017) may not reveal the breadth and depth of learning supported by a microlearning program, highlighting the need for more careful attention to the design of assessments of learning, rather than simply design of content, in microlearning.

As analysis of participants' work samples, self-assessments, discussions, and survey responses shows, effective microlearning requires adroit handling of learning objectives and careful navigation between common design recommendations, learner preferences, and the need for assessing learning. Not limited to short chunks of content that can be conveniently distributed through social media channels to help learners gain procedural skills, microlearning informed by sound application of instructional design principles can provide rich opportunities for learners both to build high-level cognitive skills and to engage with peers in the social construction of knowledge.

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Appendix

Lesson 5 pre-lesson artifact

One participant's artifact submitted prior to lesson 5 included the following explanation of grading. To maintain participant anonymity, selected words have been redacted:

You will get a "check" for showing that you have the ability/skill to execute a specific [adjective] experience. A "check" earned on the first attempt is worth at least a 9 out of 10 points. Scores of 9.2, 9.5, 9.8 may be earned if you demonstrate mastery of the specific skill and/or demonstrate a high level of creativity. Perfect scores of 10 out of 10 will seldom be given out just because I don't see this demonstration like a math test where there are absolute right or wrong answers. You will have 2 opportunities to redo your demonstration with me privately if you do not get a "check" the first time. If you receive a check on a second or third attempt, you will receive a score of 8. You will receive a 5 if the specific skill is not demonstrated after 2 re-dos.

Lesson 5 post-lesson artifact

The same participant's revision submitted at the end of lesson 5 included this analytical rubric. To maintain participant anonymity, selected words have been redacted:

Criteria	Mastering (10)	Proficient (9)	Developing (try again)
Planning	Demonstrate the proficient level work and show originality and/or creativity such as creating original [noun].	Each element of the application is presented with accuracy and clarity.	Any of the element of the application is missing and/or needing revisions.
Implementing	Execute step-by-step procedures as written in the application plan with a smooth flow and appropriate pace.	Execute step-by-step procedures as written in the application plan including [noun].	Skip some steps of the procedure or out of order. [Noun] is not presented as planned, including [specific skill not demonstrated], [specific skill not demonstrated], etc.
Facilitating	Respond in the moment to unexpected scenarios with spontaneous adaptations and/or extensions.	Demonstrate appropriate facilitating skills including eye contact, proximity, reinforcement, cueing, and prompting. Apply planned adaptation and/or extension in respond to unexpected scenarios.	Any of the facilitating skills that need more practice and improvement. Not able to respond to unexpected scenarios with planned adaptation and/or extension.
Evaluating	Identify 1 strength and 1 area of growth in the peers' demonstrations and provide constructive feedback/action plans for improvement.	Identify 1 strength and 1 area of growth in the peers' demonstrations.	Provide feedback but the feedback does not reflect the strengths and/or areas of growth in the peers' demonstrations.

Optional embedded microlearning challenges: Promoting self-directed learning and extension in a higher education course

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ABSTRACT: In higher education, learners often look to instructors to guide their learning process along a prescribed path. This case study explores how 85 students, and their 5 instructors, experienced a microlearning system consisting of microlearning challenges and corresponding micro-credentials. These microlearning challenges were embedded in a higher education course to engage learners in brief, self-directed learning tasks that served as extensions of course content. The microlearning system in this case study, called “tech-flex challenges,” was optional and implemented across five sections of an educational technology course for preservice teachers at a public university in the United States. Findings show that students had favorable perceptions of the system, but low participation rates. Students who completed microlearning challenges enjoyed them and were more likely to engage for learning purposes than to earn a micro-credential. Instructors also viewed the challenges favorably, but suggested that they should be woven into the course as a mandatory element to foster greater attention and participation.

Keywords: Digital badge, Higher education, Micro-credential, Microlearning, Self-directed learning

1. Introduction

Microlearning offers people the opportunity to pursue individual interests and learn in “short, manageable bursts” (Corbeil et al., 2021, p. 4). People engage in informal microlearning all the time, pursuing knowledge as best suits their needs and available time. However, in a formal learning setting, where the objectives and duration of the overall learning experience are institutionally predetermined, microlearning may take a different approach. A microlearning approach might be embedded in formal learning, used to chunk required content in ways that work within the curriculum (Kohler et al., 2021) and motivate learners through gamified elements (Salas, 2021). It can also be used to approach competency development with learner feedback focused on mastery as individual competencies are attained (Zhang & West, 2020). Conceptually, the integration of microlearning in a formal context challenges students and instructors to briefly isolate and focus on small chunks of learning content, whether skill or knowledge-based, which can later be woven together with other course content at a macro level.

In this study, we explore how *optional embedded microlearning challenges* (OEMC) can be designed and implemented with students in an undergraduate level educational technology course at a large public university in the United States. This OEMC system, called *tech-flex*, was designed to help preservice teachers build and extend their educational technology skills. Recognition of student accomplishments via the OEMC were recognized via micro-credentials, which took the form of digital badges. These OEMC encourage students to extend knowledge and skills developed in the regular curriculum through guided participation in co- and open-curricular activities (Kohler et al., 2021). The brief, focused nature of these challenge-based learning opportunities along with the opportunity to immediately apply the new knowledge and skills via small challenge projects and to integrate them into course assignments aligns with the general definition of microlearning (Taylor & Hung, 2022). By focusing on student engagement and perceptions as well as instructor experiences implementing the system, this study offers insights for future embedded microlearning systems.

2. Literature review

2.1. Defining microlearning

There is no single accepted definition of microlearning, although Taylor and Hung’s (2022) scoping review of 13 microlearning studies suggests a few critical characteristics of the instructional approach. They note that microlearning focuses narrowly on a specific topic, can be accomplished in a brief time, and may immediately be applied by the learner. Additionally, microlearning ideally incorporates some sort of assessment (Fennelly-Atkinson & Dyer, 2021). The specific duration of a microlearning episode is unclear, with definitions including 5 minutes or less (Nikou & Economides, 2018; Paul, 2016), 2-15 minutes (McNeill & Fitch, 2022) and 5-18

minutes (Dolasinski & Reynolds, 2020). These times are assertions or represent choices made in specific studies; per Dolansinski and Reynolds (2020) an ideal duration for a microlearning episode has yet to be empirically established.

2.2. Microlearning approaches

Microlearning is not constrained by an expected medium or instructional strategy. Examples of microlearning applications include activities focused on content consumption, such as brief educational videos (Cheng et al., 2017; Rahman et al., 2021), along with more interactive ones like questions and answer activities (Sichani et al., 2018) and videos combined with short quizzes (Triana et al., 2021). Because of the brief duration and applied nature of some microlearning, use of mobile devices as a delivery medium has been heavily explored (Lee, 2021).

Microlearning has been designed and implemented in different ways and diverse contexts. A recent systematic review found that the most frequent setting for microlearning research has been higher education, with the frequency of publications growing quickly since 2016 (Sankaranarayana et al., 2022). In higher education settings, microlearning modules have been well received by students, who enjoyed the short, focused nature of the approach (Dolasinski & Reynolds, 2021). Studies have shown that learning in this way is not only effective in terms of immediate application, but learners also perform well on a delayed post-test (Lee et al., 2021). Small, focused modules can also reduce cognitive load (Major & Calandrino, 2018) and help learners consume and retain information more efficiently (McNeill & Fitch, 2022). Learners may perceive that they have greater control over microlearning modules, enhancing retention, motivation, confidence, and achievement (Taylor & Hung, 2022).

Microlearning can be highly self-directed, with learners engaged autonomously and making choices about what they learn and how they learn it. In formal learning contexts, learners who appreciate informal and flexible learning activities with real-life meaning may react favorably to microlearning (De Gagne et al., 2019). Visions of workplace learning in the future offered by Hamilton et al. (2021) rely heavily on self-directed learning activities performed just-in-time and at small scale. The Internet has made it possible for people to freely create and share microlearning modules as open educational resources (Olivier, 2021; Word & Dennen, 2021), making it possible for learners to easily find resources for their own learning and providing instructional designers with inspiration, examples, and learning objects to adopt or adapt.

2.3. Microlearning design

In terms of design, microlearning draws from the same process model of instructional design as any other approach, cycling through some version of analysis, design, development, implementation, and evaluation (Dolasinski & Reynolds, 2020). The process is likely iterative if the goal is to make formative improvements to the design. Similarly, microlearning content and learning activities can be designed just like any other instructional content and activities, just at small scale. The same principles and strategies apply, such as Mayer's multimedia principles (Tufan, 2021). Additional considerations may be necessary depending on context, such as articulation among modules and sequencing for a microlearning-based curricula and specific technology issues for mobile microlearning (Jahnke et al., 2020).

However, designing microlearning is not a matter of breaking longer lessons into shorter ones. Although microlearning modules can be situated within a larger learning context (e.g., learners completing several related microlessons in either a formal or informal setting), the decision to use microlearning should reflect discrete learning outcomes and content that can be addressed in a brief time frame. Eldridge (2017) cautions against attempting to chunk larger units into microlearning modules simply to follow the microlearning trend. In other words, the focus of learning should not be on the scale or duration of the learning episode, but rather on what makes sense in terms of content. Even if articulated within a larger curriculum, the ability for a microlearning module to be self-contained and logically function on its own is a critical part of the approach.

2.4. Micro-credentials

Microlearning can and should be assessed, and micro-credentials are a means of acknowledging a microlearning accomplishment. They include a visual element as well as metadata that provides information about the learning activity (Gibson et al., 2015), which means they simultaneously function as motivators, pedagogical tools, and

credentials (Ahn et al., 2014). Micro-credentials are used in a variety of ways in higher education across diverse disciplines including but not limited to education (Schürmann & Quaiser-Pohl, 2022), business (Pothier, 2021), programming (Facey-Shaw et al., 2020), and visual arts and design (Fanfarelli & McDaniel, 2017). In these learning contexts, micro-credentials function to support student motivation (Peacock et al., 2020), skill development (Pothier, 2021), and course participation and interaction (Chou & He, 2017). They are not generally considered on par with formal course credit or a degree, although it has been argued that they have the potential to hold such currency should employers choose to accept them.

A familiar form of micro-credential is the digital badge. In some higher education contexts, digital badges provide a simple way to acknowledge learner accomplishments. The meaningfulness of these badges may be personal and context driven, and they may be the digital equivalent of receiving a gold star sticker on a paper, especially if the badge is merely a visual marker of progress and lacks full micro-credential metadata.

2.5. Microlearning context and design

This study is a design case that examines a microlearning system in a higher education context. In this system, optional microlearning challenges were embedded in a course with micro-credentials, in the form of digital badges, issued upon completion of each microlearning challenge. During the Spring 2022 term, 26 optional embedded microlearning opportunities were presented to students in an undergraduate educational technology course for preservice teachers. Called *tech-flex challenges* within the course, they were initially introduced during the Fall 2021 term, modeled on a similar embedded microlearning initiative implemented in a graduate level course (Arslan et al., 2022). The challenge system was revised based on instructor and learner feedback and relaunched during Spring 2022. Specifically, challenges that were timely and no longer relevant were removed and we sought to balance challenges across weeks of the course. The final list of challenges offered optional opportunities to engage in microlearning activities that were directly relevant to the course topic.

The common element of each tech-flex challenge was that students were required to “flex” their educational technology skills by independently learning something new. This challenge-focused microlearning system differs a little from other microlearning systems. Rather than providing students with learning content (e.g., a video or reading material) and then concluding with an assessment, students are given a target accomplishment, which serves as the item to be assessed, and “challenged” to develop the knowledge and skill on their own. The Internet is a vast resource, full of content and tutorials in various media formats, and one of the course objectives was for students to develop self-directed learning strategies for learning new technologies. Given a target outcome, each tech-flex challenge required students to develop and demonstrate knowledge or skills autonomously in a chosen target area.

The large number of challenges was intended to offer choice to the learners. The challenges fit under three different categories: design, technology, and networking. For design challenges, students developed their design knowledge and skills (e.g., typography, color). For technology challenges, students learned to use new tools and tool features. For networking challenges, students independently identified and interacted with people and learning resources that would enhance their careers.

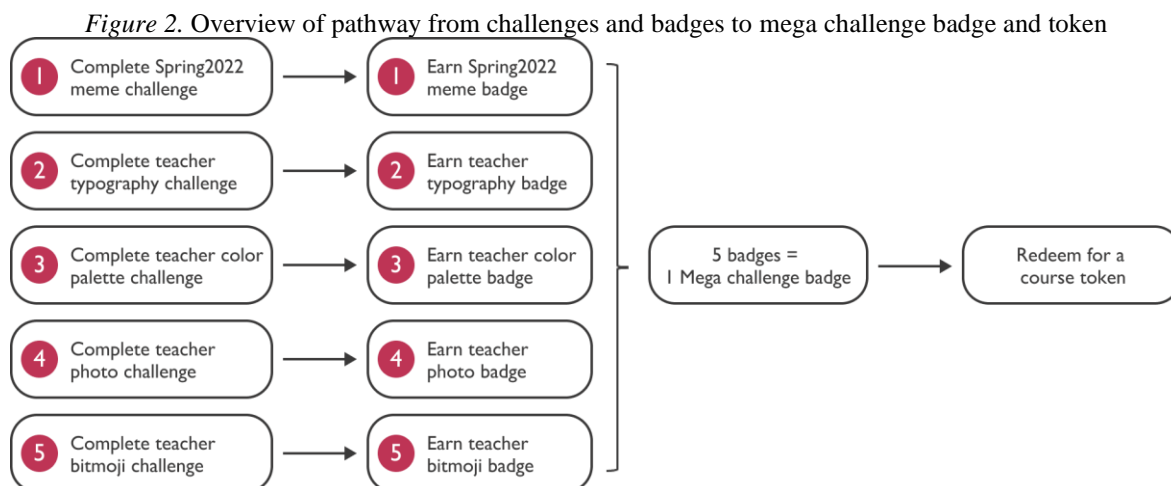
Figure 1. Sample badges



In most instances, the challenges could be completed in about 15 minutes or less, fitting Torgerson’s (2021, p. 20) definition of microlearning as “an educational experience that is focused, short, and effective,” although a few challenges were more involved. For each challenge, students produced an artifact and posted it to their blog

journal so their instructor and peers could see it (see Appendix A for a challenge, badge, and an instructor-created example). These artifacts were not formally graded, but students were offered digital badges for each completed challenge (see Figure 1).

If students completed five challenges, they were eligible to earn a mega tech-flex badge (see Figure 2 below for the pathway to earn this badge). This mega badge not only marked a student's involvement in multiple tech-flex challenges, but also could be exchanged for a token. The class used a token economy system that allowed students to self-regulate and submit tokens to excuse late work, revise work that did not meet assignment specifications, or excuse minor assignments such as graded in class activities (see Dennen & Bagdy, 2020 for more information about the token system).



3. Research questions

In this study we evaluate the effectiveness of the microlearning system design from the perspectives of the students, the instructors, and the course designers. The research questions guiding this study were:

- How and why did students engage in the opportunity to complete optional embedded microlearning challenges?
- How did students perceive the opportunity to complete optional embedded microlearning challenges?
- What did instructors perceive as the advantages and disadvantages related to using optional embedded microlearning challenges?

4. Method

This study uses a single case study research design to examine the effectiveness of the *tech-flex* OEMC system as implemented concurrently across five sections of the same course. As recommended by Yin (2003), multiple sources of evidence are used to build the case study. Although this type of study does not lead to generalizability, it provides details that help understand how and why specific outcomes (e.g., the success or failure of a project) came to be (Yin, 2013). The research design incorporates mixed methods as part of the case study, with a convergent approach, which is common among studies of this type (Guetterman & Fetters, 2018).

4.1. Participants

Participants in this study are 85 undergraduate students enrolled in five sections of a technology course for preservice teachers at a large public university in the United States, along with their five instructors and the course designers. Although gender and race data were not collected for this study, historical data from the course shows that in a typical term 60-80% of the enrolled students are female and white. Almost all students who enroll in the course are younger than 25 years old.

The course is primarily intended for preservice teachers, although during a typical term one-third of the enrolled students come from other colleges. The course also meets the university's general education computer skills requirement, which is a major reason why the non-education majors enroll. The course is taught in a fifteen-week term, and there are three sections taught in a computer lab on campus and two sections taught online in an asynchronous mode. Each class section is capped at 19 students. The study was approved by the researchers' Institutional Review Board. Participants provided informed consent.

4.2. Instruments and data collection

Data for this case study were collected from multiple sources. To address the first research question, data from the instructors' tracking spreadsheet were used to determine levels of microlearning engagement. This spreadsheet documented each time a student completed a challenge and was awarded a badge.

An end-of-course survey was used to collect data about student engagement (research question 1) and perceptions (research question 2) using Likert style items. The survey opened with demographic items and questions about prior student familiarity with micro-credentials and engagement in *tech-flex* during the class. If students did not complete any challenges, they were tracked out of the survey. If students reported completing challenges, they were asked to respond to four sets of Likert-style items. These questions focused on the importance of different *tech-flex* activities, perceptions of these activities, perceptions of micro-credentials (adapted from the Intrinsic Motivation Inventory; Center for Self-Determination Theory, n.d.), and desire to use challenge and micro-credential systems in the future. Specific survey items are documented in Tables 3-6 below.

The survey was completed by 27 students (response rate = 31.7%). Although the overall survey response rate was low, likely due to the voluntary nature of the survey and the timing at the end of the semester, the response rate for students who participated in microlearning was higher (72.2%).

Additionally, student blog posts were used to capture perceptions and reasons for engagement. Blogging was a continuous, required activity in the course, and two of the weekly blog posts related to this study. Specifically, the study considers a post in which students discussed their familiarity with micro-credentials in general at the start of the term and another with their final impression of the *tech-flex* microlearning system at the end. Participation in blog posts was high (75 of 85 students; 88.2%).

Semi-structured interviews were conducted with the course instructors and designers to address the third research question to fully capture the study context. These interviews focused on their experience and perceptions of how the *tech-flex* system functioned in the class. The course design team's design and implementation notes and other related artefacts from the course were used to fully understand the underlying rationale for the *tech-flex* system and how the system functioned.

4.3. Data analysis

Data analysis for the first and second research questions focused on descriptive statistics from the student survey, counts of challenges completed and micro-credentials earned, and thematic analysis of student blog posts. Thematic analysis focused on student prior experience with and perceptions of microlearning in general, and perceptions of and reasons for engagement in the *tech-flex* system. Themes were then used to guide content analysis based on presence of specific themes, resulting in frequency counts using the student as the unit of analysis. To answer the third research question, interviews were transcribed, and thematic analysis was used to identify positive and negative aspects of the system as well as opportunities for future improvement. Finally, illustrative quotes were identified among the blog posts and interview transcripts.

5. Findings

This section weaves together data from different sources to address the three research questions. First, student engagement data are discussed, considering both participation levels in the microlearning experience and reasons for participation. Next, student perceptions of microlearning are presented, culled from blog posts and surveys. Finally, instructor perceptions of the microlearning experience are presented.

5.1. Student engagement in microlearning

At the beginning of the term, students were asked to write a blog post about their prior engagement with micro-credentials, which offered an opportunity to learn about their pre-course knowledge and experiences. The post focused on micro-credentials, and not microlearning more generally, because we assumed students would be most familiar with the concept of credentials, such as earning physical badges through youth scouting programs. Of the 85 students, 75 (88.2%) completed the blog posts. Although many students said they had not earned micro-credentials previously, 28 (37.3%) provided concrete examples of situations where they had earned micro-credentials. Among those situations were tales of achievement recognition from fitness trackers, games, mobile apps, and scouting. Two students had experience earning micro-credentials related to learning in formal contexts while earning computer certifications.

5.2. Microlearning engagement levels

Across the five sections of the course, 18 students (21.2%; range 15.8% - 23.5% within each section) engaged in microlearning and earned a total of 63 micro-credentials. An additional 3 students completed *tech-flex* challenges, but they did not request the associated micro-credential upon completion. Among the students who completed microlearning challenges, the number of challenges completed ranged from 1 to 14. Table 1 below shows the breakdown of micro-credentials earned in each class section.

Table 1. Micro-credentials earned by class section

	Participating students	Total micro-credentials earned
Section 1 (On campus)	3	26
Section 2 (On campus)	4	7
Section 3 (On campus)	4	9
Section 4 (Online)	3	8
Section 5 (Online)	4	13
Total	18	63

There were 26 microlearning challenges issued to students, and 19 were attempted by at least one student. The seven most popular challenges are summarized in Table 2 below. Instructors reported that the students who participated in microlearning were among the top performing students in their classes.

Table 2. Most popular tech-flex challenges

Challenge	Brief description of task	Students completing challenge
Meme	Find a meme creator and create a meme about how the term is going so far. Share it to the class Slack channel.	8
Teacher Typography	Creating a typographic identity for use across all projects.	6
A Day in the Life	Research online what a day in the life of a teacher is like and create a video or infographic that addresses a day in the life.	6
Teacher Bitmoji	Create a teacher Bitmoji and post it to a blog.	5
Teacher Bio	Curate sample teacher bios and develop / post personal bio.	5
Badged Blog	Update blog sidebars, including class badge widgets.	5
Sharing “Good” Things	Use Miro and sticky notes to share on a digital whiteboard	5

5.3. Reasons for engaging in microlearning

Students shared various reasons for engaging in microlearning in their blog posts. Some students saw the connections between the microlearning challenges and other assignments, as expressed in these comments:

I feel like the [challenges] thus far have given me the opportunity to better understand the projects we have. Doing so has allowed for me to put the skills I learn during the lesson to use and better understand the functions of the program we are using. [Final blog post]

These weekly challenges gave us additional practice with technology and the subjects we covered in class. ... The issue I found with the tech-flex challenges is that after a certain point, I stopped doing them because my other classes got a bit intense. However, I still think they are fun and could be implemented in my classroom down the road. [Final blog post]

Other students found the outcomes of the microlearning system motivating. Although only one student earned and redeemed a token through their microlearning participation, 17 students (22.7%) mentioned in their blogs that they liked the ability to earn a token by participating. The student who earned the token shared, “I have thoroughly enjoyed the various little activities and challenges that I had to complete.”

Time and workload were commonly mentioned reasons for not participating in the microlearning activities, with 37 students (49.3%) indicating that they lacked time to complete (more) challenges and 11 (14.7%) commenting that they did not participate because it was optional. Finally, one student from an online section of the course was entirely befuddled at the end of the term, writing in their blog, “Tech flex challenges confuse me. At the start of the semester, I must have missed the section explaining tech flex challenges.”

Thirteen of the students who completed the survey indicated that they had participated in *tech-flex* challenges, representing 72.2% of the 18 students who participated in microlearning during the course. These students shared their reasons for engaging in the challenges using a 5-point Likert scale ranging from *Not at all important* (1) to *Extremely important* (5). Their top reasons were to learn tools and earn badges (see Table 3 below). Students were least interested in seeing what classmates were doing, with 5 of the 13 rating that item as *not at all important*.

Table 3. Importance of different tech-flex activities for participating students ($n = 13$)

Item	Mean	SD
Completing tech-flex activities to learn a new tool.	3.77	0.70
Completing tech-flex activities to earn a micro-credential.	3.08	1.07
Seeing how many tech-flex activities I could complete.	2.92	1.07
Seeing how many micro-credentials I could earn.	2.62	1.21
Seeing how my classmates completed tech-flex activities.	2.15	1.17

Students also were asked about their motivation to earn micro-credentials. Most were very (4; 30.8%) or somewhat (7; 53.9%) motivated by the micro-credentials, with only 2 (15.4%) finding these not at all motivating. However, 5 students (38.5%) were not at all motivated by the mega challenges, which involved completing 5 microlearning challenges and could be rewarded via a course token.

5.4. Student perceptions of microlearning and micro-credentials

The second research question addresses student perceptions of microlearning. On the survey, students were asked to agree with statements related to how they perceived *tech-flex* activities using a 5-point scale from *Strongly disagree* (1) to *Strongly agree* (5). Overall, the 13 students who completed *tech-flex* activities felt they offered an effective approach for learning (see Table 4 below). All five items related to learning and achievement received mean ratings of 4 (*Agree*) or higher. The item with the lowest mean related to the importance of grades and suggests that students were not overly concerned with whether the *tech-flex* activities themselves received a grade. In this sense, it appears that students who completed the tasks either had a learning orientation toward the class or recognized that skills developed through these tasks might enhance performance on graded class activities. *Tech-flex* activities were deemed time-consuming by some students; those same students indicated difficulty deciding what to do for *tech-flex* tasks.

These 13 students were also asked to share their perceptions of the micro-credential earning experience using a 5-point scale ranging from *Strongly disagree* (1) to *Strongly agree* (5). As shown in Table 5 below, the students who earned micro-credentials recognized the voluntary, optional nature of the activities. For many of these students the micro-credentials held some value; the mean on items about value and being beneficial is above the midpoint. However, students were equally split on the question of whether they put a lot of effort into earning micro-credentials, with a mean at the scale midpoint and an equal distribution on each side of that midpoint.

Finally, students were asked to indicate their desire to engage in this type of microlearning experience again. As shown in Table 6 below, all but one of the students who tried the *tech-flex* challenges was open to having the student experience again. Interestingly, for some students there was greater interest in using microlearning and micro-credentials as a teacher than as a student. In that sense, the activity served as a model of an instructional strategy for these pre-service teachers. There was the least enthusiasm for using a microlearning system at work.

Table 4. Perceptions of tech-flex activities for participating students (n = 13)

Items	Mean	SD
Tech-flex activities are effective for learning new knowledge.	4.23	1.05
Completing tech-flex activities provides me with a sense of achievement.	4.08	1.00
Completing tech-flex activities helps develop class knowledge efficiently.	4.08	1.14
Completing tech-flex activities helps develop class knowledge effectively.	4.08	1.14
I learned something new while completing tech-flex activities.	4.00	1.11
I enjoyed completing tech-flex activities.	3.85	1.10
I am self-motivated by completing tech-flex activities.	3.54	1.28
Tech-flex activities are too time consuming.	3.38	0.84
I chose my tech-flex activities based on whatever would take the least time.	3.23	1.31
It was difficult to decide what to do for tech-flex activities.	0.08	1.00
Tech-flex activities are unimportant because they are not graded.	0.54	1.22

Table 5. Student perceptions of micro-credentials (n = 13)

Item	Mean	SD
I believe I had some choice about earning micro-credentials.	4.38	1.15
I earned micro-credentials because I wanted to.	4.31	1.14
I think earning micro-credentials could help me to learn something.	4.08	1.27
Earning micro-credentials was fun to do.	4.00	1.18
I believe earning micro-credentials was beneficial to me.	3.92	1.07
I would be willing to earn micro-credentials again because it has some value to me.	3.85	1.23
I put a lot of effort into earning micro-credentials.	3.00	1.24
I earned micro-credentials because I felt I had to.	2.00	0.96
There may be good reasons to earn micro-credentials, but personally I don't see any.	1.62	0.74

Note. Scale adapted from Intrinsic Motivation Inventory (Center for Self-Determination Theory (n.d.)).

Table 6. Future interest in challenges and badges (n = 13)

Would you like to use a microlearning system again?	Not at all	Somewhat	A lot
As a student	1 7.7%	9 69.2%	3 23.1%
As a teacher	2 15.4%	4 30.8%	7 53.9%
At work	7 53.9%	5 38.5%	1 7.7%
For personal/informal learning	4 30.8%	5 38.5%	4 30.8%

Four students left open comments at the end of the survey. One indicated that they would have liked to earn extra credit rather than tokens. Another said they found it difficult to decide which challenges to do and what to do for them. A third shared that they struggled with time and felt a compulsion to complete the challenges in order, rather than picking and choosing among them, and as a result they gave up after three challenges even though some of the later challenges were tempting. The final comment was positive and stated that the system offered “a great opportunity to gain more real experience in different areas of technology to become better accustomed to them.”

5.5. Positive perceptions from blog posts

On their initial blog posts, most students (47; 62.7%) solely reported positive sentiments toward micro-credentials. The remainder were negative (5; 6.7%), neutral (7; 9.3%) or mixed (16; 21.3%) in their sentiments. Students offering mixed sentiments made negative comments about micro-credentials, but counterbalanced these negative statements with acknowledgements that some people might like or see value in them. Students with a

neutral perspective wrote factual statements (e.g., *Badges can be used to reward achievements.*) without taking a stand about their value.

Most students with positive sentiments identified micro-credentials as a means of documenting accomplishments or achievements (59; 78.7%) and learning (48; 64.0%). Micro-credentials were also deemed fun (45; 52.9%) and cool (19; 25.3%). About one-third of the students (27; 36.0%) commented on the capability of micro-credentials to motivate learners; each of these students was also among the group of students describing micro-credentials as fun and/or cool.

5.6. Negative perceptions from blog posts

Negative perceptions frequently related to the meaningfulness of micro-credentials. One student commented:

“[They] are like getting a treat for reaching a goal. They have no real meaning but can make a person feel better and use a source more because they got rewarded. ... I think it just tricks people into using a product or site more. While they can be effective I do not personally use them. [Initial student blog post]

Another student wrote, “For me, however, the idea of being rewarded for completing simple tasks via a digital badge is... demeaning. Needless to say, it is not a concept I will be implementing when I teach.” Unsurprisingly, neither of these students engaged with microlearning in the class, with one commenting, “I’m not too concerned with knowing how to do all the little intricate things that technology allows for; only the stuff that I need to get by as an educator and individual.” In all but one instance, negative comments came from students who did not engage in microlearning. That student stated:

I only did one [tech-flex challenge] this semester I think and it was honestly not my favorite assignment. I just don’t really care about badges because I don’t know where to put them and I don’t think they really matter much outside of this class. [Final blog post]

Unfortunately, this student did not write more about why they chose to participate in optional microlearning that they did not enjoy, nor did they share which task they completed.

5.7. Instructor perceptions of microlearning

The instructors were familiar with the concepts of microlearning when the Spring 2022 term began. Three of the instructors indicated that they earned micro-credentials as graduate students during their coursework, and one had learned about it from a peer. All five instructors had implemented the first version of the *tech-flex* challenge system during Fall 2021 in their respective sections of the course and provided feedback for improvement at that time.

5.8. The participation challenge

All the instructors commented on low participation rates in *tech-flex* challenges, attributing it to the optional nature of the activities. Still, four instructors indicated that a subset of their students freely engaged in microlearning. The fifth instructor indicated that none of the students in her section, which was online and asynchronous, participated in microlearning of their own volition. Later in the course, she introduced some of the challenge activities as an alternate assignment for students who needed one for the subject pool participation assignment. Subject pool participation, in which students participate in 2 hours of educational research via a subject pool in the college, is a required and graded component of the course worth 2% of the final grade. Instructors are required to offer alternate assignment options to students who do not wish to engage in research. The general sentiment toward the value of microlearning challenges, despite low participation, was summed up by one instructor who commented, “I think it is good, it expands the learning opportunities, but it’s based on their willingness.”

The instructors were asked how their students reacted to the microlearning system when it was first introduced in their classes. Their experiences differed somewhat by modality. Instructors teaching campus sections of the course were able to present the *tech-flex* system during a class session and see the immediate reactions of their students. One campus instructor shared that students felt comfortable after they learned that *tech-flex* challenges would be optional. The instructor continued, “After I introduced the concept, [a student] mentioned that she was

familiar with it and she even shared what she produced... So that was fun.” That student had experienced challenges in another course, and showed the class a photo of how she dressed her dog for a challenge that she participated in.” The instructor continued, “I think saying that it is optional made them feel comfortable, at least what I sensed from the class.” The other campus instructors also indicated that some of their students were interested in *tech-flex* challenges, although others did not react much.

In the online sections, *tech-flex* was introduced to students asynchronously. Information was provided to students in a module, with no guarantee that students would engage with the content. One of the online instructors indicated that she was unaware of student reactions, stating, “Actually, because I have taught ... asynchronous online courses, I couldn’t see the immediate reaction from the students. I’m not sure what they thought about it, because none of them actually sent me an email to ask about it.” The other online instructor mentioned a mixed response from the students. Still, participation levels in the campus and online sections were similar (see Table 1).

5.9. Positive experiences of microlearning engagement

Throughout the term, instructors shared that when students completed challenges, the overall reactions were positive. One instructor stated:

There are some students, they are really interested in the tech-flex challenges. Actually, I also have at least four of them and they do some challenges. One completed at least 10 challenges. So that is very nice. [Instructor interview]

Another instructor mentioned how she enjoyed it when students included her in their challenges, referencing her instruction and the other course assignments, including creating a meme about her. She said, “These kinds of items were funny because it’s like, they’re not just completing this assignment, but they also think about the relationship with their instructors. I really appreciated those connections.”

Students not only referenced instructors in challenges, but also noticed what their peers were doing. One instructor shared about an informal chat initiated by a student after class in which the student mentioned seeing micro-credentials shared in one of her classmate’s blog journals, and asked how she could also share micro-credentials on her blog journal. The instructor commented that the interaction had been a highlight of the *tech-flex* experience, seeing a student motivated by a peer’s accomplishments and asking to learn more about it.

Two instructors indicated that they also had new insights and learned new things from challenges and developed their ideas of how microlearning could be integrated in formal learning contexts. One instructor commented how teaching with the *tech-flex* system made her pay attention to microlearning and micro-credentials in everyday life and offered a connection point with students:

I knew the purpose behind it, but I think when I see my students are very active in earning badges and proud of earning these badges, it’s motivated me to see badges in different ways. So for instance, when I finished a workout, I noticed I earned digital badges from my Apple Watch. And then I was so happy and shared with my students, and they also liked my post. So, I think it increased the interaction between me and students. [Instructor interview]

Another instructor shared her experiences with the Canva video challenge, which she chose to do on her own. She said, “if the procedure is really difficult to learn [students] just skip it and but I did it, it was so fun. So after that challenge, actually, I started to create a title page using Canva, inserted a video saying hello to students ... I liked it.”

5.10. Microlearning system limitations and recommendations

Instructors identified limitations with the overall microlearning system design and implementation and offered several ideas for improvement. Many of the limitations and recommendations surrounded optional participation and its effect on participation levels, a topic mentioned by all the instructors. One instructor recommended mentioning the *tech-flex* system in the syllabus and during the first class session to call more attention to it. Others pointed out that if microlearning is required and graded, students will pay attention. However, the instructors need to be motivated to focus on *tech-flex* too, with one saying, “So I actually didn’t spend a lot of time on exploring the challenge items. But if this is part of the activities required for the class, I believe I will take my time to explore things.”

Adding microlearning challenges as a required element of the class is possible, but perhaps not practical. With a weekly blog post assignment and other solo and group assignments, students were already submitting 1-2 items to be graded each week. In-class time is provided for working on some assignments, but instructors indicated great variability in the student experience. One instructor's experience was that, "it is easy for some students but for other students, they really need a lot of time." Another instructor was concerned about students feeling overloaded with tasks, stating, "I didn't want them to be stressed out so I emphasized that it is optional so that they cannot be confused with other assignments, and they don't get like overwhelmed by all the list of work that they have to do."

The instructors drew parallels between *tech-flex* challenges and an existing portfolio assignment. For their portfolio, students were asked to submit a digital portfolio twice during the term, providing evidence of specific technology skills they had developed. Although most of the portfolio items were prescribed, relating to skills students needed to demonstrate to meet the course objectives, others offered choice, much like the *tech-flex* challenges. One instructor suggested that the challenges, which she enjoyed, could be folded into the portfolio requirement.

Other recommendations offered by instructors related to having more structure and consistency in the *tech-flex* system. Specifically, they suggested: Start and end dates for each challenge; an equal number of challenges each week; an equal scope for each challenge; and a set difficulty level of each challenge. Due dates would help instructors plan for grading, because "I know it's not a like big workload, but it still takes some time and mentally it could be stressful [to keep up with]." Due dates might also motivate students to complete challenges. One instructor commented, "Lots of flexibility also confused them. So maybe it's also helpful for both of us if there is like an expected timeline."

Finally, tracking challenge completion and awarding micro-credentials was a limitation of the current system. All the instructors shared that they struggled with this task owing to the manual nature of the process and the lack of deadlines. Because challenge evidence was presented on students' blog journals, instructors did not get an alert in the learning management system (LMS) when there was a challenge item to be assessed. At least one instructor had overlooked a challenge submission and was alerted by a student to award the associated micro-credential. Additionally, monitoring blogs for challenge completion was a low priority activity because it did not relate to student grades.

6. Discussion

6.1. Student engagement and perceptions of microlearning

The first two research questions asked about student engagement and perceptions. Overall, student perceptions of the *tech-flex* challenge system were positive, whether students participated in microlearning or not. Most students who participated in challenges recognized them as an opportunity to learn something new. However, engagement was relatively low. Time and voluntariness were frequently cited as barriers to participation from both the student and instructor perspective. Motivating voluntary learners is one of the biggest challenges of any optional learning experience (Jones & Korula, 2021), and similar issues have been found with other optional microlearning implementations (Beste, 2023), as well as optional learning activities in other contexts (Ruipérez-Valiente et al., 2016).

An unanticipated benefit of the *tech-flex* challenges, whether students completed them or not, was greater awareness of how the required knowledge and skills being taught in class could be extended. This worked because the challenges were intentionally sequenced as recommended by Jahnke et al. (2020), complementing required course tasks. Merely reading the challenges exposed students to new ideas about what they could learn in a short period of time. Per instructor reports, much like with extra credit work (Harrison et al., 2011) and findings from other studies of microlearning in higher education (Reid et al., 2015), high performing students and students who valued learning completed the challenges, suggesting that students who were primed for extension activities used the challenges in this way. However, because students submitted their challenge work on their blogs, visible to their classmates, their classmates could benefit vicariously.

None of the microlearning challenges found in De Gagne's et al. (2019) scoping review – pedagogical discomfort, technology inequalities, and privacy concerns – were raised in this study. That may reflect the nature of the class, which already had students interacting online and heavily using technologies. In other words, issues of this nature were not unique to the microlearning activities in this course and were addressed and mitigated in the larger course design.

6.2. Instructor perceptions of microlearning

From the instructor perspective, which was investigated by the second research question, the idea of learning through challenges was never questioned, but the use of optional challenges was. Instructor recommendations focused on streamlining and structuring the system, as well as making it required. Although none of the instructors suggested abandoning the challenges, and they enjoyed seeing what students did for the challenges, they also raised issues about student workload and existing assignments. The issue here was not scope, but number of assignments.

From an implementation perspective, instructors did not emphasize *tech-flex* challenges with their students because they deemed required assignments more important – and rightfully so. Instructors were concerned with their students who needed more time and help to complete the regular assignments, and promoting and tracking challenge completion was a secondary priority. As an extra element of the class, an additional workload burden was created for instructors much like when extra credit opportunities are provided (Pynes, 2014). This burden could be somewhat alleviated by technology, although none of the existing LMS-integrated micro-credential tools were available for use in this course.

6.3. Evaluating the system

Philosophically a conundrum is raised by these findings. The system was viewed favorably for the just-in-time, small-scale, self-directed learning that it could inspire. However, in order to generate widespread engagement both students and instructors indicated that required participation is needed. Some instructors alluded to offering less choice, too. Requiring participation, however, would change some aspects of the *tech-flex* challenges. For example, students might expect explicit instruction if challenges were required, and could be reluctant to engage in self-directed learning and exploration. Also, student perceptions of the system might have been less favorable had it not been optional or had it not involved choice.

Critics are often quick to suggest that low participation is problematic, but in a non-compulsory system perhaps that value judgment should be reconsidered. There is precedent for reconsidering the importance of full participation or completion in the MOOC literature, recognizing that in voluntary learning contexts learners may find value in following their own paths or observing others (Dennen & Bong, 2017). In the *tech-flex* system, the optional activities represent extended application of learning concepts, not extra but ungraded practice that supports performance on course assessments. The consequences of not participating are low, and the value of participation is personal enrichment, much like informal forms of microlearning that occur outside of formal learning contexts. Low participation could be a reason to discontinue offering the challenges if supporting the system is burdensome for instructors, but if system maintenance does not require additional labor, then there is no harm done.

The *tech-flex* system was designed to support the development of self-directed technology learning skills, and choice and autonomy are hallmarks of self-directed learning (Brandt, 2020). However, autonomy is not typical in formal learning contexts. Participation and choice could be separated in future iterations of the *tech-flex* system. In other words, microlearning challenges could be integrated as a required element, and yet students could choose among the challenges they complete. This solution would scaffold self-directed learning, providing constrained choice and encouraging autonomy within those constrained choices. Providing student choice is established as a learner-centered principle and can motivate learners (Bonk & Dennen, 2003; Bonk & Dennen, 2007). Similarly, microlearning in authentic, everyday contexts involves choice. People choose what they want to learn or problems they want to solve and then identify their own learning paths. By requiring students to make choices about challenges, they would begin to learn how to navigate the paradox of choice associated with self-directed learning (Brockett, 2006). The use of challenges, as opposed to designed instructional modules, supports autonomy in a micro sense; learners must leverage their existing knowledge, skills, and the Internet to address the challenges. These supported challenge learning experiences could prepare students for the greater choice and autonomy that adult learners face in their everyday lives solving authentic problems.

6.4. Implementing microlearning

Microlearning system implementation is an important consideration for optional or required systems. In this study, instructors were given minimal directions other than to share the *tech-flex* system with their students, monitor progress, and award micro-credentials. Instructors were not given guidance about how to promote or talk about microlearning with their students. In particular, this issue arose as a shortcoming in online course sections.

Greater effort could be made to formally introduce the system at the start of the semester, as recommended by Facey-Shaw et al. (2020), even if challenges are not yet being issued.

In this study, the first time students were made aware of the microlearning system, was a few weeks into the course. The blog posts used as data in this study were written at that time, but they focused primarily on micro-credentials, reflecting both a reading assignment and corresponding prompt. Inverting the focus from micro-credentials to microlearning by providing readings about microlearning and directly showing how the challenges are a form of microlearning might be helpful to promote student awareness. Similarly, a brief reading and prompt about self-directed learning could help students understand why the microlearning challenge approach is being used.

6.5. Microlearning and motivation

Although motivation was not formally measured in this study, the findings nonetheless suggest that most students had relatively low extrinsic motivation to complete challenges and any intrinsic motivation was counter-balanced by a variety of competing, higher-priority tasks. Drawing from Keller's (1987) ARCS model, it becomes worthwhile to consider whether the challenges were noticed by students (attention) and whether students recognized how the outcomes of the microlearning activities related to bigger course assignments and their future activities as teachers (relevance). Seeing a model or a demonstration or having more structure to support microlearning might increase confidence. Finally, satisfaction might be a more difficult dimension to support, but for some students it may come from receiving attention or acknowledgement of their work. The micro-credentials offered through *tech-flex* challenges were meant to support student satisfaction, but they had little meaning beyond the class, and students were aware. Horstman et al. (2020) noted the importance of micro-credentials having value in other settings, but systemic change at a higher level would be needed to make that happen. Thus, micro-credentials may not be effective because they are not widely acknowledged elsewhere in the curriculum. However, portfolios could provide another means to document and acknowledge student microlearning accomplishments in a format that is more widely recognized in educational settings.

In future iterations of the system, there are opportunities to gain student attention by making the system required and introducing it on the first day of class. Relevance could be enhanced by connecting student microlearning accomplishments to courses later in the curriculum. A student showcase of microlearning projects is one idea that could generate satisfaction for some students, while giving others the confidence that they, too, could succeed at these challenges.

7. Limitations

This study has several limitations. First, the student response rate for the final survey was low. We were pleased that the response rate among microlearning participants was higher than the overall response rate, but would have still liked a greater response from students. Time and voluntariness were likely the reasons for lack of survey response and lack of microlearning participation, but nonetheless it would be helpful to know more about what might encourage these students to participate in challenges and whether they would feel satisfied by attaining the outcomes associated with the challenges.

We did not collect uniform data about the implementation of *tech-flex* across each class section, although we know that system introduction and awareness differed, particularly between the campus and online sections of the class. Online sections had lower awareness, which likely reflected the asynchronous nature of the course instruction. Online students had to purposefully engage with instructor-provided announcements and content to learn about challenges and badges, whereas campus students who attended class would be exposed to microlearning challenges so long as they paid attention.

Finally, there was potential for error in the tracking system. This system was manual due to the lack of a micro-credential platform integrated into the learning management system. Tracking student *tech-flex* accomplishments proved onerous and was secondary to grading assignments and other course tasks.

8. Implications

This study offers several implications for practitioners who wish to implement microlearning systems in their formal learning contexts. First, it is important to offer choice, but too much choice may be overwhelming to students. Choice might be structured slightly, perhaps by offering students categories of learning options (e.g., students must complete something related to graphics, but there are four options to choose from). Second, while micro-credentials may seem like an obvious way to reward students for engaging in microlearning, it is important to make sure that learning is the focus and not earning micro-credentials. This implication conflicts somewhat with Beste's (2021) recommendation that increased gamification might motivate participants, and is based on the general student disinterest in competitiveness in this study. Further, a microlearning system connected to grades might be more successful, allowing instructors to dispense with the complexity of micro-credentials and a secondary assessment system. Alternatively, students could have a minimum threshold to meet and then earn some form of extra credit or other recognition for each bit of learning above the minimum. Finally, optional learning opportunities should be temporally structured for students. In other words, the opportunities can be released to students when they correspond with course units or assessments, and then closed when those units and assessments have passed.

9. Conclusion

This case study demonstrates how microlearning challenges can be issued to students in higher education, encouraging them to use their self-directed learning skills and the Internet to accomplish the challenge tasks. With small-scale tasks, self-directed learning is manageable for university students, although if optional, these tasks will be a low priority. The use of micro-credentials to motivate learner engagement in microlearning challenges appears to be limited. Although some learners appreciate receiving the recognition, absent a larger system of academic recognition and currency, class designed and issued micro-credentials hold little meaning and might easily be replaced by other forms of achievement recognition, including grades.

This study adds to the existing body of research on microlearning in higher education by showing the role of microlearning as a form of course extension, providing structure and encouragement for students to explore knowledge and skills that lie just beyond or adjacent to regular course expectations. Future research might explore differences between self-directed microlearning, like the *tech-flex* challenges, and instructor-designed and prescribed microlearning, to explore differences in motivation and learning outcomes. Additionally, future research should determine if there is a connection between developing self-directed microlearning skills in a supportive environment like a university course and being able to successfully use microlearning to support professional development later in life.

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Appendix A: Challenge and badge example

Teacher Bitmoji

Show me your bitmoji! I'll go first...

Here are two bitmojis created by one of the EME2040 instructors, Ömer



Look at some of the resources below! You'll see that so many teachers are having lots of fun with bitmoji in and out of the classroom!

- Educators turn to bitmoji to build community and engagement (Links to an external resource)
- What's the "Bitmoji craze for educators" all about? (Links to an external resource)
- 5 reasons why teachers love the bitmoji classroom (Links to an external resource)

Well... if you don't have a bitmoji, let's create it together in this tech-flex!
Follow the directions below, complete the task, and earn the Teacher Bitmoji badge.

Directions

1. Create a bitmoji account.
 - Here's a resource that can help you create an account (<https://support.bitmoji.com/hc/en-us/articles/360001493786-Create-a-Bitmoji-Account>)
2. Design your teacher bitmoji.
 - Here's another resource that can help you get started with designing your teacher bitmoji (<https://support.bitmoji.com/hc/en-us/articles/360001493806-Create-Bitmoji-with-a-Selfie>)
3. Make a blog post about how you created your teacher Bitmoji. Don't forget to add your bitmoji to your blog!
4. Your instructor will be awarding this badge to your Cluster portfolio upon the completion of the task.



Creating the conditions for professional digital competence through microlearning

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ABSTRACT: Teachers fostering future-ready graduates need to master updated pedagogical and technological knowledge, so teacher professional development (TPD) is essential. Conventional TPD activities such as seminars and workshops are limited as they require specific time blocks and lack flexibility. The current study investigated TPD through microlearning courses in online and blended learning modes as an innovative TPD approach in Hong Kong. We applied a qualitative approach and thirty-two preservice teachers in the English language education program participated. The data were collected using questionnaires, semi-structured interviews, and observations for data collection. The pre-service teachers' digital competencies were evaluated against an observation protocol based on the SAMR framework and TPACK model. The effects of microlearning and the participants' digital competence needs were also identified. The results revealed how preservice teachers perceived the integration of technology and the challenges they encountered (e.g., design of learning tasks and time management). Based on the findings, personalized and hands-on training is recommended to fulfill teachers' diverse learning targets in applying specific technology and deepen their understanding of technology use. Furthermore, as more conceptual frameworks for assisting microlearning in TPD are necessary, this study can help enrich the underpinning theories for the microlearning design of TPD.

Keywords: Microlearning, Pre-service teachers, Digital competence, Technology, Pedagogy

1. Introduction

The recent advancement of digital tools and related infrastructure in many educational contexts due to the COVID-19 pandemic has led to a rapid rise in the use of digital technology in English language lessons (Moorhouse & Kohnke, 2021). As a result, increasing attention has been paid to teachers' digital competence (Starkey, 2020) and ability to integrate technology effectively into their lessons (Hafner & Ho, 2020). There are many teacher professional development (TPD) models (e.g., Consuegra & Engels, 2016; Huang et al., 2022; Zhao, 2010); remarkably, only a limited number of studies focus specifically on online and blended learning (OBL) (Philipsen et al., 2019). Therefore, many teachers struggle to realise the full potential of OBL strategies and become proficient in them. This is partially because many models of TPD follow a linear approach and mode of delivery (e.g., short courses, workshops; Richards & Farrell, 2005) and assume all participants have similar starting points (Weston et al., 2018). One emerging approach, microlearning, has recently received attention because it can deliver tailored, meaningful, timely, self-directed TPD with small, highly focused learning objectives (Zhang & West, 2019). Microlearning typically comprises bite-sized learning nuggets (i.e., 1–6 minutes) that are based on multimodal input (e.g., infographics, videos), focused on a specific topic to prevent cognitive overload and accessible anytime and anywhere (Corbeil et al., 2021). To address the requirement that English language teachers adopt new approaches and stay current in their instruction, this study analyses data from pre-service teachers in Hong Kong who participated in a short TPD course on OBL delivered via microlearning. It aims to understand and conceptualise the effects of microlearning and its ability to create the conditions for professional digital competence in teachers' future practices.

1.1. Teacher professional development with microlearning

The goal of TPD is to foster instructors' knowledge and skills in their respective fields (Desimone, 2009; Kennedy, 2016). Specifically, in Hong Kong (the context of the current study), the Education Bureau of the Government of the HKSAR (EDB, 2020) divided TPD into three areas: (1) professional competencies, (2) professional values and conduct, and (3) aspiration for self-advancement through self-reflection. Of the TPD training events devised for teachers, mentors, and school leaders, participatory activities (e.g., workshops, observation/evaluation of lessons, and professional development days) are considered the most effective (Policy

21, 2017). However, barriers to engaging teachers in the activities have also been mentioned. These include: (1) lack of time to attend the activities because of a heavy workload, (2) scheduling conflicts with fixed events, and (3) undesirable activity venues (Policy 21, 2017). To relieve these issues, the current study considers microlearning (specifically, microlearning delivered online), which is an emerging framework introduced in the early 2000s (Hug, 2005) that promotes “chunking” to reduce the cognitive overload that comes with exposure to new information (Gobet, 2005).

Microlearning aims to convert complex data into bite-sized, easily-digestible units of learning, each of which has a single objective (Corbeil et al., 2021). It allows learners to learn on demand, anytime and anywhere, using mobile-friendly platforms (Kohnke, 2021; Kohnke & Fount, 2023). Accordingly, TPD on OBL can be delivered in small chunks that address a single learning concept and can be accessed using technology (Zhang & West, 2019). For example, microlearning can include image-based learning (e.g., infographics, memes, animated GIFs), audio-based learning (e.g., podcasts), and video-based learning (e.g., screencasts, vlogs) (Kohnke, 2023). Activities can be made adaptable and flexible by embracing technology and multimodal features. Earlier studies have found that microlearning can enhance satisfaction, motivation, and learning performance by providing autonomy, encouraging self-directed learning, and maximizing efficacy (Kohnke et al., 2023; Nikou & Economides, 2018). With the potential benefits of microlearning, such as faster learning, higher engagement and interactivity, and personalized learning experiences, the aforementioned issues with TPD on OBL may be relieved. Therefore, the current study aims to use microlearning to facilitate TPD which promotes digital competence.

To integrate microlearning into TPD training, the current study has considered previous TPD models. The conceptual framework developed by Desimone (2009) – addressed in many previous studies (e.g., Didion et al., 2020; Whitworth & Chiu, 2015) – proposed methods to engage teachers in the learning process and enhance the sustainability of TPD. The framework identified five features (i.e., “content focus,” “active learning,” “coherence,” “sustained duration” and “collective participation”) to consider when designing TPD activities (Desimone & Pak, 2017; Desimone, 2009). The framework suggested that the learning content should be subject-specific, consider the methods students use to learn, and align with the expectations of multilevel systems (e.g., teachers, schools, and governments; Desimone, 2009). Meanwhile, it posited that TPD is sustainable when it supports better educational practices and the activities are consistent with the policies and goals of the school (e.g., aligned to the curriculum, suitable in terms of duration and frequency; Desimone & Stuckey, 2014). As microlearning is limited to a few minutes and can be designed and delivered online, learners are free to choose their study time and the learning content can be edited quickly and easily if school policies change.

Furthermore, Kennedy (2016) suggested that focusing on TPD design features may not be sufficient to guarantee that it will yield positive results. For example, focusing on content knowledge exclusively may not lead to positive performance, as expected – the actual design of the learning experience should be considered systematically (Kennedy, 2016). Similarly, after analyzing the interactions of three subsystems (i.e., teacher, school, and activity), Opfer and Pedder (2011) proposed that there is not only one way to achieve a learning goal: actual results are affected by the specific learning context, which is a dynamic system. Therefore, the methods of connecting different stakeholders and encouraging them to participate in TPD became a core issue.

Subsequently, an iterative design for TPD was proposed. This approach aims to use teachers’ feedback to modify and improve the design of TPD activities; the new activities are then implemented to obtain additional feedback. It is accompanied by collaborative learning (e.g., Fishman et al., 2013; Voogt et al., 2015). The assumption is that TPD can be made sustainable and scalable by combining iterative design with collaborative learning, as this will allow TPD to be adapted to specific contexts (Clarke & Dede, 2009). By engaging various stakeholders to participate in the design and evaluation processes, the learning content of microlearning will become more aligned with schools’ and teachers’ needs (see Section 1.3).

In short, to sustain and scale up the transformation of TPD, previous models have emphasised the importance of interactions among different stakeholders, alignment between the content and the expectations of various actors (e.g., teachers, school leaders, schools, and governments), and modifying the content using iterative design. Therefore, microlearning content should be established on an online platform that allows different stakeholders to edit and comment quickly and synchronously. Meanwhile, microlearning should not be designed as a single source that both delivers and evaluates teachers’ professional knowledge – in the iterative design of TPD with microlearning, learning results should be evaluated based on actual practice (e.g., teaching performance) as well.

1.2. TPD for digital competence

Over the past three years, as institutions worldwide transitioned from a face-to-face to a virtual learning environment (Hodges et al., 2020) teachers have been required to acquire new skills and knowledge and quickly expand their digital competence (Moorhouse & Kohnke, 2021). Furthermore, this transition altered their beliefs about technology-infused teaching and their pedagogical roles (Moorhouse et al., 2022). Although schools offer regular TPD on OBL to develop teachers' digital competence, it tends to focus on *how* to use technology rather than *why* to do so or how to integrate it with existing course materials (Tondeur et al., 2015). Previous studies have established that teachers' pedagogical beliefs determine how they use technology in the classroom (Eickelmann & Vennemann, 2017) and they tend to only integrate technology if this aligns with their concept of effective teaching (Ertmer et al., 2015). As a result, TPD activities may be ineffective if they fail to connect with actual teaching practices or offer a clear vision of how technology can complement and support learning (Lim & Wang, 2016). To address this issue, personalised TPD is a crucial way to increase teachers' digital competence and bring about positive change in their practice (Shamir-Inbal & Blau, 2020). Furthermore, Lim et al. (2021) suggested incorporating professional learning communities as a form of TPD, so teachers can receive continual support while developing their digital competence.

1.2.1. *Technological, Pedagogical, and Content Knowledge (TPACK) model*

Another of the most widely adopted models in previous studies (e.g., Jen et al., 2016; Schmid et al., 2021) is the Technological, Pedagogical, and Content Knowledge (TPACK) model proposed by Mishra and Koehler (2006), which aims to promote the application of technology and enhance students' learning performance. The TPACK model proposes a framework of the knowledge required for teachers to integrate technology into education (Koehler & Mishra, 2009; Yeh et al., 2021). Technological knowledge relates to handling digital tools and integrating them into the instructional process. Pedagogical knowledge refers to the practice of imparting knowledge. Content knowledge refers to the understanding of a specific subject. The combination of the three elements leads to a comprehensive consideration of instructional design. For example, pedagogical content knowledge considers how particular teaching approaches apply to specific material (Koehler & Mishra, 2009).

The TPACK model has been used to design courses equipped with digital learning tools (Pözl-Stefanec & Geißler, 2022). Meanwhile, previous research has found that, although pre-service teachers were confident in pedagogical knowledge (PK), technological knowledge (TK), and pedagogical content knowledge (PCK), they felt challenged by technological pedagogical knowledge (TPK; Valtonen et al., 2020). Dalal et al. (2021) conducted a semester-long technology course for secondary school teachers and evaluated their TPACK based on the technology-based lesson plans they designed. They found that the teachers improved in all TPACK domains, with the largest growth in technological content knowledge and technological content pedagogical knowledge. The teachers were able to identify the affordances of technology based on content and pedagogical requirements. By combining TPACK with hands-on experiences using the "learning by design" strategy, teachers will be able to integrate technology into their teaching practices effectively (Yeh et al., 2021).

1.2.2. *Substitution Augmentation Modification Redefinition (SAMR) technology integration model*

Moreover, the Substitution Augmentation Modification Redefinition (SAMR) technology integration model (Puentedura, 2006) can be used to evaluate the extent to which technology is applied in education and scaffold teachers' understanding of technology use (Bicalho et al., 2022; Hamilton et al., 2016; Tunjera & Chigona, 2020). The SAMR model identifies four levels of technology use: (1) *Substitution*: simply using the technology without adjustment; (2) *Augmentation*: improving traditional tasks with technology; (3) *Modification*: redesigning traditional tasks significantly using technology; and (4) *Redefinition*: creating new tasks based on the technology (Hamilton et al., 2016). Utilising the SAMR model, educators can evaluate the state of technology integration and provide targeted support to facilitate further integration. Research has shown that the model can enhance teachers' awareness of technology use and its integration into education (Harmandaoğlu Baz et al., 2018). Additionally, combining the SAMR model with other frameworks, such as TPACK (e.g., Hilton, 2016; Tunjera & Chigona, 2020), offers a comprehensive approach to guide teachers to design instruction that integrates technology effectively.

1.3. TPD for digital competence in Hong Kong

As the current study was conducted in Hong Kong, it is necessary to consider this context specifically. In Hong Kong, teachers' digital competence refers to the ability to adopt technology to facilitate the acquisition of 21st-century skills and cultivate students' ability to be self-directed learners (EDB, 2015). The Hong Kong Education Bureau (EDB, 2018) has further divided digital competence into five series: e-leadership, e-safety, pedagogical, subject-related, and technological. To promote teachers' digital competence and readiness to adopt e-learning in their classes, the EDB has suggested implementing professional development programmes, fostering learning communities, and encouraging reflective practice (EDB, 2015; EDB, 2018). Specifically, it has recommended that professional development equip teachers with essential knowledge of the latest instructional techniques used in e-learning (EDB, 2018). Learning communities allow teachers to share their experiences and provide mutual support to resolve issues (EDB, 2015). Furthermore, they facilitate teachers' adoption of new teaching materials and pedagogies (Law et al., 2011). Actively reflecting on issues can enhance teachers' proficiency in applying new knowledge (Moon, 2006).

Committee on Professional Development of Teachers and Principals (COTAP, 2015) collected relevant data and evidence in Hong Kong to inform TPD strategies and policies and established the "T-dataset^{PD}" based on a territory-wide survey (see <https://www.cotap.hk/index.php/en/t-dataset>). In their responses, novice teachers indicated that professional development programmes for digital competence "prepared them well to become a teacher holistically" (Policy 21, 2017, p. 15). However, they also raised some issues with the programmes. They said that the programmes were more helpful in the "teaching and learning" domain than the "student development" domain, presumably because they place greater emphasis on teaching than general personal development (Policy 21, 2017). Furthermore, the teachers reported they were not adequately prepared to cultivate creativity and self-direction in their students, respond to societal changes, assess the impact of their changes on social values, or become active in the educational community and volunteer work (Policy 21, 2017). Accordingly, in Hong Kong, there is an urgent need to provide quality TPD on OBL to improve teachers' digital competence, help them integrate technology effectively, and bring about positive student outcomes.

1.4. Study objectives

Considering the increasing importance of teachers' digital competence and the potential of microlearning as a TPD approach, this study focuses on pre-service teachers (PSTs) in Hong Kong who participated in a short TPD course via microlearning. The study aims to explore the effects of microlearning and its ability to create the conditions for professional digital competence in teachers' future practices.

Specifically, the study seeks to:

- Investigate the perceptions of PSTs regarding the effectiveness and relevance of microlearning as a TPD approach to develop digital competence
- Explore how microlearning can affect the integration of technology into teaching practices and the adoption of innovative instructional strategies
- Identify the challenges and opportunities associated with implementing microlearning as a TPD approach for PSTs in the context of education in Hong Kong.

While the current study focused exclusively on PSTs and did not include in-service teachers, we assumed that the participants, who had teaching experience during their internships, would be capable of making connections between their teaching experience and the learning content. This understanding allowed them to provide valuable insights into the requirements for developing professional digital competence through microlearning. Furthermore, considering the similar levels of teaching experience among novice teachers and the PSTs invited to participate, the results of the current study are expected to be generalizable to novice teachers.

2. Methodology

This qualitative case study is firmly grounded within the interpretive paradigm, where each participant is viewed as a unique, standalone case. Qualitative research, noted for its in-depth exploration of "how" and "why" questions (Myers, 2009), lends itself to the descriptive and exploratory nature of this study. The multiple-case study approach allows researchers to gain "a unique example of real people in real situations" (Cohen et al., 2018, p. 289) and facilitates a thorough portrayal of phenomena, subjective experiences, and perceptions. In the context of this study, this approach will provide a picture of teachers' digital competence needs by drawing on

abundant and multi-faceted data from questionnaires, semi-structured interviews, and observations. Additionally, by focusing on the underexplored area of microlearning TPD for English language teachers, we will contribute to theory building in this evolving field (Yin, 2009).

Moreover, this study delves into the ways microlearning can support sustainable e-learning practices among teachers. Because it can deliver bite-sized, focused segments of learning, microlearning encourages the active engagement and self-guided exploration of digital tools, which is critical for effective e-learning. This helps to foster digital competence, TPACK awareness, and SAMR integration among teachers, which are becoming increasingly important in the current digital education landscape. Thus, while qualitative research explains teachers' experiences and needs in the realm of digital competence, it also lays the groundwork for investigating the potential benefits of microlearning in terms of fostering effective and sustainable e-learning practices. This approach is even more pertinent considering that microlearning is a burgeoning field in which the existing theoretical and conceptual frameworks may not provide a comprehensive understanding. The case study method, therefore, serves as a fitting lens to explore, analyze, and contribute to this expanding discourse. This study addresses the following research questions:

- RQ1. To what extent does microlearning influence pre-service teachers' digital competence, TPACK awareness, and SAMR integration?
- RQ2. How does microlearning influence pre-service teachers' digital competence, TPACK awareness, and SAMR integration?

2.1. Participants

The first step of recruitment was to offer one semester long course in Spring 2022, which focused on integrating e-learning resources in primary and secondary schools. Thirty-two of the 36 participants in the course (22 women and 10 men) aged between 20-23 expressed interest in joining this study. The participants were third, fourth, or fifth (final) year pre-service English language teachers studying either primary or secondary education.

All 36 course participants were informed of the nature of the study in writing and completed the pre-course questionnaire (see Appendix A). However, the findings presented below represent the 32 participants who agreed to join the study and provided their informed consent. Among the 32 participants, twelve volunteered to participate in semi-structured interviews (see Appendix B) and observations (see Appendix C). The remaining course participants ($n = 4$) have the same access to any materials described in this study, but their data were not presented in this study. See Table 1 for participant profiles.

Table 1. Profile of the participants (observations, interviews)

Participant (Pseudonym)	Gender	Age	Year
Jacob	M	23	5
Mona	F	20	3
Anna	F	21	3
Raymond	F	21	4
Alex	M	21	4
Brian	M	21	3
Robert	M	23	5
Sonia	F	23	5
Billy	M	22	4
Samantha	F	22	4
Shane	M	22	5
Anna	F	21	3

2.2. Microlearning course design

As microlearning is a new course format for teachers in Hong Kong, it was important to give the participants (pre-service English teachers) first-hand experience engaging in and developing such lessons. The elective 13-week course that participants in their third, fourth, or fifth year can enroll in as part of their degree plan was designed based on the information gathered in the pre-course questionnaire and included the following features:

- introduction to the rationale and principles of using technology to support English language teaching and learning

- instruction on using technology to enhance English language teaching and learning
- introduction to applications, websites, and related activities useful for developing microlearning lessons
- tips on “getting it right” in the context of the Hong Kong English curriculum.

The microlearning approach to TPD was carried out according to the following procedure:

- introduction to microlearning via short podcasts (3 mins each) and formative assessments using Mentimeter (5 questions per podcast)
- technology instruction via short videos (4–5 mins) developed using Edpuzzle
- applications and websites introduced through a short face-to-face presentation (6 mins), followed by step-by-step instructions and tips developed using Canva (infographics)
- tips for success delivered using animated flashcards made with Quizlet and recorded videos (4–6 mins).

Participants had access to a rich resource repository on Moodle containing short-form content that they could consume at their pace and according to their priorities. Some of the topics and tools were related to SAMR, ways to engage students with technology, classroom management when using technology, creating interactive worksheets, e-book creation, virtual reality, comic strips, and animation. In addition, they could use a discussion forum to reflect on and share their experiences. To ensure that the course remained on-topic and engaging, the content was presented in small chunks and focused on the aforementioned learning outcomes. This structure was intended to make it less monotonous than traditional courses and help the participants retain the information.

2.3. Data collection

This study incorporated three phases of data collection, each designed to address the research questions. In the first phase, participants were asked to complete a qualitative online survey (see Appendix A), which collected their demographic details, perceived digital competence, and perceptions of microlearning as a professional development tool. Subsequently, they underwent personalized training on professional digital competence and engaged in microlearning lessons on integrating technology integration.

During the second phase, twelve participants volunteered for classroom observations; their lessons were video recorded. These observations focused on how and why participants integrated technology into their lessons (i.e., the influence of microlearning on their digital competence and TPACK awareness). To capture the degree of technology integration, an observation protocol grounded in Puentedura’s (2006) SAMR framework, was developed (see Appendix B). This was also designed to identify the TPACK-based knowledge required to teach with technology effectively, aligning with Mishra and Koehler’s (2006) TPACK model. Following each observation, participants were encouraged to reflect on their teaching using the prompts provided.

The third phase involved two-part individual interviews in English with the same twelve participants. The first part utilized a stimulated recall methodology (participants were shown a video sequence and invited to reflect) (Nguyen et al., 2013), while the second employed a conventional semi-structured interview guide to stimulate discussion about the teachers’ digital competence, their perceptions of the microlearning course, and how it influenced their integration of technology. All of the interviews, lasting 35–50 minutes, were audio-recorded and transcribed verbatim.

Throughout the study, the team of four researchers remained in constant communication, devising the procedures and tools (e.g., questionnaire, prompts, and interview guide) collaboratively and ensuring that the data collected were congruent with the research questions.

2.4. Data analysis

The study produced a rich dataset that included multiple perspectives. There were three data sources: the qualitative survey, observations, and semi-structured interviews. The questionnaire data were analysed using descriptive statistics to meaningfully summarize the participants’ responses (Jansen, 2010) and provide a general understanding of their personal and professional digital competence, knowledge of how to integrate technology into their lessons, and perceptions of microlearning.

We watched the lesson recordings and read the interview transcripts repeatedly to familiarize ourselves with the data. During the process, we took observational notes and recorded possible themes. We shared these themes using Google Docs; then, we noted and discussed similarities and differences.

In the next stage of the data analysis, the lead researcher conducted a more detailed analysis of each case using a thematic analysis approach (Braun & Clarke, 2006). All of the lesson observations and interviews were analysed in detail. A summary of each case was created using the initial themes, and the summaries were compared. At this stage, the analysis was shared and discussed with the three other researchers, and the themes were finalized.

Finally, extracts were selected to exemplify the final themes and offer insights into the participants' digital competence. The various datasets were cross-checked to ensure the credibility and trustworthiness of the findings (Braun & Clarke, 2006). In addition, the participants were allowed to review the transcripts, themes, and quotes through member checks (Merriam & Tisdell, 2016).

3. Findings

The findings of this study illuminate that microlearning increased the digital competence of the pre-service teachers and helped them recognize the skills they needed to engage in digital pedagogy. By analysing the datasets, we generated five main themes related to professional digital competence. Each theme addressed both RQ1 and RQ2. Participants' interview responses are presented verbatim in the following section.

3.1. Lack of confidence

The results of the pre-course survey showed that the majority of pre-service teachers were uncomfortable using digital tools to engage their students in learning. Over two-thirds (69%; $N = 22$) indicated that they lacked confidence due to their unfamiliarity with digital tools and how they can be used to facilitate English language learning. The remaining participants (31%; $N = 10$) indicated that they were somewhat confident. In other words, the pre-service teachers did not have much faith in their digital competence. They reported in the interviews that they find it relatively easy to use Kahoot! or Mentimeter for formative assessments. However, using applications that use multimodal approaches or digital storytelling felt overwhelming, and many did not know where to start. Jacob, for example, found that using applications for personal use did not transfer to teaching:

If you ask me, I'm confident in using social media, computers... I enjoy checking Facebook and posting tweets. But I don't know how I can integrate a range of technology with my future learners. I think it is not easy to understand how technology can actually support good language learning.

Mona also lacked confidence in her ability to leverage digital resources:

One of the key reasons [I am not confident] is that I need to teach using the textbook provided by the school. Meanwhile, we are required to incorporate technology into the lessons. This means I must discover the "right" tech and create e-activities suitable for my students. I wouldn't know where to begin.

The other participants' answers were similar. Anna stated, "The relationship between personal and professional use is different." Raymond said, "You know, just because we are 'young', we are expected to know how to use it with our students automatically." In the present study, the participants attributed their lack of confidence leveraging technology in their teaching practice to the little previous formal training they had received. Alex noted, "Courses to integrate technology in the classroom are optional in our degree."

3.2. SAMR

In the pre-course survey, the participants indicated they do not know how to create content. Only two (6%) indicated being confident that they could produce digital teaching content, although six (19%) said they could engage in basic content editing and 14 (44%) were confident in their ability to modify and improve existing digital content. However, it was clear from the observations and interviews that the participants could create digital content, so their content creation skills must have developed as they participated in the microlearning course.

At first, a majority of the participants indicated that they found it challenging to create digital resources. A majority of participants indicated that they were unsure which applications to use and how to engage their learners. However, after attending the microlearning course, the majority of pre-service teachers felt increasingly confident that they could use digital tools to create material and engage students in English language learning. For example, Brian explained how he created an e-book using the SAMR framework:

I used the e-book software that was introduced in our training. I moved the reading text and added the built-in text-to-speech features so students could read and listen to the text as it was read. Then, I linked the new vocabulary to Oxford Learner's Dictionaries, and I encouraged everyone to share a review of the text on our Instagram account.

Alex also utilized the SAMR framework to modify an assignment about tourist locations in Hong Kong:

Students read about typical tourist spots in their books, which can be tedious. So, to excite them, I downloaded a map of Hong Kong, used Thinglink [an Augmented Reality application] and created tags that the student could click on, covering the different districts that introduced the spots using videos created by EdPuzzle. Then, they had to select their favourite one and make a digital travel brochure incorporating multimedia and a student-created video.

Other participants discussed incorporating comic strips, interactive worksheets, and flashcards to digitize existing materials. The interviews showed that microlearning provided the teachers with the knowledge and skills they needed to use technology and the SAMR model helped them think about its role in supporting learning.

In the observations, the participants incorporated many digital tools into their lessons to engage their students, using various platforms (e.g., Wordwall, Nearpod, Edpuzzle) to meet their learners' diverse needs. For example, three participants created PowToons to introduce and reinforce aspects of grammar and five used comic strips created with Canva to present new vocabulary. However, further analysis showed that most of the participants only substituted digital teaching materials for physical ones (the first stage of the SAMR model). Robert shared that "identifying one task that fits all of the four definitions of the SAMR model is difficult;" instead, he tried "to think about how [he] can simply modify a task." Sonia also mentioned that incorporating all four components would "be too time-consuming, not only for me but we won't have enough lesson time for the students for the redefinition."

3.3. Classroom management

Before taking the course, 21 (66%) of the participants reported that time management was a challenge when using digital tools in the classroom. Nineteen (59%) felt the same way about managing supportive interactions and behaviours.

We observed that all of the participants integrated digital resources into their lessons but appeared to struggle with classroom management as students worked on their iPads. Only three out of the 12 participants gave clear instructions before the activity and managed to keep their students on-task. Billy explained: "Students were excited, I didn't want to disrupt them by asking them to keep their voices down." Samantha echoed this: "They were happy, and I thought most were working on the activity." Given the difficulties of monitoring the class and the potential for confusion when working with technology, students need to receive clear instructions. In the interviews, the participants realized that incorporating technology in their lessons was challenging – not only because each form of technology is unique but also because of the pedagogical skills required to use them effectively.

They perceived this to be a limitation of microlearning. When asked to elaborate, Jacob mentioned that he had focused on building up his "technical know-how" in order to "design good activities for his students." This sentiment was shared among the participants; technical knowledge took precedence over pedagogy even though, in the microlearning course, these two aspects were given equal weight. This suggests that future courses should focus on digital pedagogy, as participants can learn the required technical skills but still lack the skills to manage their classrooms.

3.4. Personalized training

In the pre-course questionnaire, over two-thirds of the participants (69%; $N = 22$) indicated that it was important for the course to meet their individual needs. Interestingly, 29 (90%) reported that it should focus on specific tools and 24 (76%) said it should be social. Later, the participants mentioned that they all had different levels of digital competence, and microlearning allowed them to select relevant and appropriate content. Shane shared that the “sense of autonomy helped me build on my existing skills without being forced to study what I’m not interested in.” Anna added:

The video overviews and step-by-step instructions gave me a really good insight into how I could use them [digital tools] in my teaching. But there was one tool, I think it was Lino, I felt it didn’t really do anything, so after the video, I forgot about it.

Similarly, Anna stated:

I liked that I could watch a short video and kind of figure out what the tech was about. And if I didn’t like it, I didn’t need to do anything else. I think this is a really good way to deepen our knowledge of available technology and decide if it would work for us when we teach.

These comments illustrate that introducing new technology and pedagogy using short, focused segments of learning allows participants to decide what is practical and easy for them to use. The flexibility of microlearning can also make participants more confident in selecting digital tools.

Even though the course was delivered using microlearning and each segment was relatively short, the participants also felt that it provided a form of collective learning because of the multimodal elements (e.g., videos, podcasts, infographics) and built-in discussion forums. Brian noted, “This made me more motivated...I felt we were learning together.” Others added that the online forum helped them reflect on ways to modify their teaching practices and support each other. Therefore, this aspect of the course also increased the participants’ understanding of how digital tools can facilitate learning in the classroom.

3.5. Hands-on training

Microlearning also gave the participants ample opportunity for hands-on practice, which allowed them to handle digital tools and practice integrating them into their teaching. Mona said, “I consider myself not very good with technology, so I’m very hesitant to use technology in my lesson. So, playing around with so many tools without pressure really helped me to overcome my uncertainty.” Likewise, Alex appreciated the “opportunity to experiment with and explore a range of cool tools.” Raymond added, “The link to theory became clearer during the practical part as I could experience it first-hand.”

Brian said, “I found the prompts provided [helped] me to understand how I can get the best from the technology.” When asked to elaborate, he specified that he liked “figuring out which features work best for me.” The participatory element of microlearning allowed the participants to expand their practical skills and develop new ideas of how to use technology to impart content knowledge. They found that the microlearning design elements of the course not only taught them how to use technology but also understand why they should do so.

3.6. Summary

In summary, concerning RQ1 (“To what extent does microlearning influence pre-service teachers’ digital competence, TPACK awareness, and SAMR integration?”), this study indicates that microlearning impacts all three areas significantly. Initially, many of the participants lacked confidence in leveraging digital tools for teaching due to their unfamiliarity with such resources and the perceived disconnect between personal and professional use. Yet, after undergoing microlearning training, they were more confident and could create digital content using various forms of technology, guided by the SAMR model. The microlearning course also facilitated personalized learning, allowing them to focus on tools relevant to their needs and interests. Its hands-on aspect helped them overcome hesitations and uncertainties. However, there were challenges. For example, some participants struggled with classroom management when integrating digital resources into their lessons, suggesting that future training and courses should focus on digital pedagogy. Furthermore, most participants only substituted digital materials for physical ones, indicating they had not fully maximized the potential of digital technologies as described in the SAMR model. Overall, microlearning has a significant but nuanced influence on pre-service teachers’ digital competence, TPACK awareness, and SAMR integration.

Concerning RQ2 (“How does microlearning influence pre-service teachers’ digital competence, TPACK awareness, and SAMR integration?”), this research indicates that it does so in the following six ways:

- Microlearning appears to boost pre-service teachers’ confidence in utilizing digital tools to facilitate English language learning. Prior to the microlearning course, many of the pre-service teachers expressed discomfort and little confidence in using digital tools. However, as they progressed through the course, their confidence increased, indicating an enhancement in their digital competence.
- The SAMR framework in the microlearning course helped pre-service teachers understand how digital tools can support learning. Although initially most of them only substituted digital teaching materials for physical ones, the model helped them think about how to augment, modify, and even redefine tasks using technology.
- While the pre-service teachers recognized that they struggled with classroom management when integrating digital resources, the microlearning course provided an environment in which they could experiment with the required skills. This highlights the need for future courses to focus on digital pedagogy.
- The microlearning course allowed pre-service teachers to select the content that met their needs, contributing to a sense of autonomy. This personalization helped them build on their existing skills and improve their digital competence.
- Even though the course was composed of short segments, it provided social benefits that made learning a collective experience. The online forums, discussions, and multimodal elements (e.g., videos and podcasts) facilitated peer learning and experience-sharing, enhancing teachers’ TPACK and providing examples of how others integrate the different forms of knowledge.
- The course also offered significant hands-on practice, allowing pre-service teachers to explore and familiarize themselves with various digital tools, which likely improved their digital competence and understanding of how to integrate technology into teaching.

4. Discussion and conclusion

The current study has showcased the intricate and challenging process of developing digital competence in pre-service teachers, with a focus on the pivotal role of microlearning. By actively engaging in microlearning tasks, the participants strengthened the digital skills that are for professional growth, facilitating the seamless integration of technology into OBL classrooms. Despite being limited to primary and secondary school teachers in Hong Kong, this qualitative study broadens the understanding of enhancing teachers’ digital competence through microlearning, an essential TPD approach.

In our exploration of microlearning, two core elements emerged: (1) concentrated, practical training and (2) a supportive, reflective environment. This approach can be applied to both pre-service and in-service teachers. It enabled the participants to use technological tools effectively; many of the digital practices we saw in the observations emerged directly from the course. One notable example was the use of the e-book tools in software such as Nearpod, Thinglink, and Edpuzzle to convert traditional print resources into interactive and engaging digital learning materials. However, this had an unexpected impact on oral interactions in the classroom (Moorhouse et al., 2021), highlighting the need for an iterative approach informed by microlearning principles to help teachers adapt their teaching practices.

Our analysis also examined how teachers incorporated various tools that were introduced in the microlearning course. They effectively employed student response systems (e.g., Kahoot!, Mentimeter) for formative assessments and online platforms (e.g., Padlet) for brainstorming activities. Their increased confidence in incorporating technology in their teaching indicates the effectiveness of the microlearning approach. However, it also underscores the necessity of going beyond technical skills and focusing on developing teachers’ digital pedagogy and ensuring alignment with local contexts (Hubbard, 2018).

The English language teachers’ heightened awareness and aptitude in using digital tools after the microlearning course demonstrates its effectiveness for both pre-service and in-service teachers (Kohnke et al., 2023). They were able to devise appropriate teaching materials for the face-to-face classroom, despite occasional frustrations and difficulties concerning classroom management when digital tools were the primary learning resources (An et al., 2021).

The results of this study illustrate the potential of microlearning in cultivating skilled, competent teachers as they demonstrated and expressed digital competence after participating in the course. It allows teachers to direct their own learning and choose the easily digestible learning segments that they find most beneficial (Shamir-Inbal & Blau, 2020). Aligning with principles of informal learning, microlearning encourages learners to decide what,

when, and where they learn, fostering the continuous development of their digital competence. Through the systematic design of TPD that encompasses microlearning, it is possible to cater to the needs of all stakeholders, ensuring that learning is context-specific, collaborative, and relevant (Kennedy, 2016; Opfer & Pedder, 2011; Voogt et al., 2015).

However, this relatively small-scale qualitative case study cannot be generalized to other teachers or contexts. Nevertheless, it provides a starting point for more extensive studies. Accordingly, future research could examine whether there are significant differences related to TPACK and SAMR if the course were taken by in-service teachers in Hong Kong or other contexts. In addition, professional development providers can consider how to develop the most effective activities based on continuous feedback and, thus, implement a cyclical process to increase teachers' competence (e.g., Voogt et al., 2015). Finally, readers will need to choose the ideal way to implement microlearning based on their particular contexts and the technology available.

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Appendix A: Sample questionnaire questions

- Q1. What is your gender?
- Q2. What is your age?
- Q3. How confident are you in using digital tools to engage students in learning?
- Not confident at all
 - Slightly confident
 - Somewhat confident
 - Quite confident
 - Very confident
- Q4. How confident are you in producing digital content?
- Not confident at all
 - Slightly confident
 - Somewhat confident
 - Quite confident
 - Very confident
- Q5. How confident are you in engaging in basic content editing?
- Not confident at all
 - Slightly confident
 - Somewhat confident
 - Quite confident
 - Very confident
- Q6. How confident are you in modifying and improving existing digital content?
- Not confident at all
 - Slightly confident
 - Somewhat confident
 - Quite confident
 - Very confident
- Q7. What is the most challenging aspect of using digital tools in the classroom? (open)
- Q8. What is the most important part of digital competency training? (open)

Appendix B: Sample interview questions

- Can you tell us what tools you prefer to use and why?
- How did you learn to use these tools?
- In your teaching, which digital tools did you use? Why?
- In your teaching, what is the most challenging with using digital tools?
- In your teaching, are there any digital tools you would like to learn how to use? Why?
- Based on your experience participating in microlearning, what are the main differences between traditional training and microlearning?
- Has microlearning helped you to develop your digital competency? What have been the essential components? Why?

Appendix C: Sample observation protocol

- Technology resources (ratio technology/student)
- Digital tools being used
- Skills (listening, speaking, writing, reading)
- Student learning activities
- Interactions (independently, collaboratively [pair/group])
- Teacher roles (e.g., facilitation, modelling, presenting)
- Teacher proficiency
- Student proficiency
- Classroom management
- Other observations

Roles and functionalities of ChatGPT for students with different growth mindsets: Findings of drawing analysis

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ABSTRACT: With the rapid development of generative artificial intelligence (GAI), the performance and usability of related tools, such as ChatGPT, have significantly improved. The advancement has fostered researchers to increasingly focus on students' perceptions and application of the roles, functionalities, and interaction patterns of these tools in higher education. The present study adopted the draw-a-picture technique to explore the viewpoints and conceptions of undergraduates with different growth mindsets regarding the roles and functionalities of ChatGPT in learning. It also analyzed their interaction process with ChatGPT, especially their interaction skills and question types. The results showed that there were significant differences in the conceptions of "locations," "learning content," and "learning activities" of students with different growth mindsets. In the interaction process between undergraduates and ChatGPT, significant differences existed in the interaction skills and question types of students with different growth mindsets. Besides, students with different growth mindsets also had different learning achievements and critical thinking tendencies. The findings revealed the conceptions of students with different growth mindsets regarding the roles and functionalities of ChatGPT in learning, and also provided valuable insights for teachers. These findings are beneficial for educators to more accurately adjust and optimize the application of these tools in teaching activities based on students' different growth mindsets.

Keywords: Draw-a-picture technique, Growth mindsets, Generative artificial intelligence, GAI, Undergraduates

1. Introduction

As generative artificial intelligence (GAI) continues to evolve, ChatGPT has had a significant influence on teaching approaches in higher education. Most educational studies have indicated that ChatGPT has the ability to promote personalized learning and higher-order thinking (Baidoo-Anu & Owusu Ansah, 2023; Chan, 2023). GAI plays multiple significant roles in education, such as teacher/tutor, student/tutee, learning peer/partner, domain expert, administrator, and learning tool (Hwang & Chen, 2023). GAI technologies (e.g., ChatGPT) not only attract attention in the field of education but also prompt educational practitioners to actively explore their potential application in teaching and learning (Lim et al., 2023; Strzelecki, 2023). Specifically, researchers have pointed out that ChatGPT can enhance the flexibility, autonomy and comprehensiveness of the learning environment, which are believed to bring various benefits to learners (Heimans et al., 2023; Mohamed, 2023; Rospigliosi, 2023). For instance, Jeon and Lee (2023) specified that chatbots (e.g., ChatGPT) not only served as content providers, teaching assistants, and evaluators, but also acted as partners for learners to practice conversation with. However, the influence of ChatGPT goes far beyond this, as it has been applied in various fields of education, such as medicine, science, engineering, and computing education (Arif et al., 2023; Berdanier & Alley, 2023; Cooper, 2023; Firat, 2023).

In the field of higher education, the main function of ChatGPT is to generate highly innovative output through interaction with users, thereby enriching students' learning experience. This includes serving as a writing assistant, teaching art and design methods, as well as acting as a research support tool (Chan & Hu, 2023; Kasneci et al., 2023). Some researchers have disclosed that information literacy plays a crucial role in the operation of ChatGPT. Especially when seeking and evaluating information, learners need to apply their critical thinking skills to determine whether the information provided by ChatGPT is accurate and credible (Lund & Agbaji, 2023; Yan, 2023). Lo (2023) introduced the CLEAR framework as a guiding methodology for prompt engineering in educational settings. This framework encapsulates five core principles: conciseness, logical coherence, explicitness, adaptability, and reflectiveness. The application of the CLEAR framework is posited to facilitate more effective student engagement with AI-generated content, particularly in ChatGPT. The study argues that this approach fosters the development of critical thinking skills, which are increasingly essential in this era of advanced conversational agents. Besides, ChatGPT emphasizes question-oriented dialogue and in-depth exploration of knowledge, combines real-time interaction, adaptability and personalization, and can enhance student engagement. This has caused ChatGPT to attract increasing attention in the field of higher education (Chan, 2023; Mohamed, 2023). While ChatGPT-related research mainly focuses on social implications, technological development and application, how learners in higher education perceive and utilize ChatGPT in learning contexts has received little attention. Researchers have revealed that in terms of the roles

and functionalities of ChatGPT in learning, exploring and investigating learners' perceptions, learning performance, and communication modes is crucial to assist learners' effective learning (Hwang & Chen, 2023; Wu et al., 2023). In addition, researchers have uncovered that learners' growth mindset may affect their acceptance or performance in new technological environments (Liu et al., 2022; Yeh et al., 2023). A few studies have also verified that possessing a growth mindset can not only affect learners' engagement, motivation and learning behaviors, but also improve their information literacy and academic achievements (Cheng et al., 2021; Tewell, 2020). Based on the situations and needs of students in higher education, it is necessary to understand their expected learning modes, conceptions and communication skills for the roles and functionalities of ChatGPT in learning (Hsieh & Tsai, 2018; Hwang et al., 2023; Lai, 2021).

Previous research mainly adopted questionnaires to understand learners' attitudes towards the use of ChatGPT, with limited focus on exploring undergraduates' perceptions and conceptions of the roles and functionalities of ChatGPT in learning based on their experiences. Moreover, mixed methods have attracted increasing attention from researchers in educational research (Chang et al., 2022a). For instance, Gal (2023) used multiple analysis methods (including drawing analysis, reflection analysis, and analysis of course summary work) to evaluate the impact of pedagogy in university education. The use of the draw-a-picture technique allows participants to express their viewpoints through a combination of visual and textual elements. It also provides researchers with a comprehensive and in-depth way to understand learners' perceptions and interpretations of specific concepts (Chang & Tsai, 2023; Hsieh & Tsai, 2017; Hsieh & Tsai, 2018). Above all, this study employed the draw-a-picture technique to explore the viewpoints and conceptions of students with different growth mindsets regarding the roles and functionalities of ChatGPT in learning. This study also analyzed the interaction between students with different growth mindsets and ChatGPT, with a focus on interaction skills and question types. Additionally, it further examined the influences of different growth mindsets on students' learning achievement and critical thinking tendency. These research findings not only provide researchers with new insights into the application of ChatGPT in educational contexts, but also serve as valuable guidance for educational practitioners on how to more effectively integrate ChatGPT into higher education learning environments.

2. Literature review

2.1. Students' conceptions of roles and functionalities of ChatGPT in learning

ChatGPT, a GAI-based chatbot, has achieved widespread recognition and significant influences in the field of higher education (Chan & Hu, 2023; Farazouli et al., 2023; Fauzi et al., 2023). It not only provides an innovative learning environment, but, more importantly, creates a way for students to deeply engage with and explore various types of information (Baidoo-Anu & Owusu Ansah, 2023). Engaging in personalized and in-depth conversations with ChatGPT not only helps students to understand various academic conceptions from more diverse perspectives, but also effectively stimulates their thinking ability and creativity (Rospigliosi, 2023). In terms of language teaching, particularly in English writing, Yan (2023) specified that ChatGPT played an auxiliary role in grammar checking and feedback. Furthermore, it stated that due to academic integrity and plagiarism during the training stage, most scholars still had reservations about the application of ChatGPT in this field. Therefore, integrating ChatGPT into the teaching process is not only a technological innovation, but also an important means to enhance education quality and AI literacy (Chan, 2023; Farrokhnia et al., 2023).

Nonetheless, the conceptions of roles and functionalities of ChatGPT in learning are multifaceted and complex. In the field of language education, it can not only serve as an interlocutor and content provider, but also as a teaching assistant and evaluator. Educators need to use professional teaching knowledge to integrate various resources, inspiring students to become more proactive researchers and enhancing students' AI ethics awareness when using AI tools (Cotton et al., 2023; Jeon & Lee, 2023). Farrokhnia et al. (2023) examined the application of ChatGPT in the field of education by using the SWOT (i.e., Strengths, Weaknesses, Opportunities, and Threats) framework. They highlighted that ChatGPT could provide personalized learning and alleviate teachers' burden. Yet, it might also result in a deficiency in students' in-depth understanding and critical thinking, which potentially increased the risk of academic dishonesty. Several researchers have clearly defined ChatGPT in learning, illustrated how it can be applied in education (e.g., Farrokhnia et al., 2023; Hwang & Chen, 2023; Lim et al., 2023), proposed the CLEAR framework (Lo, 2023), and adopted a survey to investigate the influencing factors of using ChatGPT (Liu & Ma, 2023; Strzelecki, 2023). For example, Chan and Hu (2023) revealed that understanding students' attitudes and concerns about using GAI tools was particularly critical for educational practitioners, which could help promote students' learning motivation and learning outcomes. Liu and Ma (2023) pinpointed that attitudes played an extremely important role in predicting learners' behavioral intentions of using

ChatGPT. This finding implied that if EFL learners had a positive attitude towards ChatGPT, they were more likely to use this tool for learning in informal or leisure activities.

However, in the field of higher education, there has been a lack of exploration into how students perceive and utilize the roles and functionalities of ChatGPT in learning from various perspectives, particularly concerning students with different growth mindsets. Understanding these conceptions and perspectives is of crucial importance for the design and integration of this tool in educational practices. To fill this research gap, this study mainly adopted the draw-a-picture technique as a research method and focused on students with different growth mindsets. Moreover, to provide a good reference for designing and developing ChatGPT-integrated learning and training activities, this study also analyzed students' interaction processes with ChatGPT, as well as their learning achievement, and the critical thinking tendency of students with different growth mindsets in the ChatGPT-integrated learning activities. These research results can serve as guidance and a reference for the integration of ChatGPT or similar tools in future teaching and training activities.

2.2. Drawing as a research approach

Drawing is not only a means of visual expression, but it has various other functions, including perception, communication, invention, and action (Adams, 2017; Tu et al., 2021). With regard to educational evaluation, drawing has been verified as an effective formative assessment tool, which is particularly valuable for capturing and assessing learners' conceptual understanding in specific domains (Chang & Tsai, 2023; Chang et al., 2020; Hsieh & Tsai, 2017; Selwyn et al., 2009). Additionally, scholars such as Lai (2021) and Zhang et al. (2023) have indicated that the draw-a-picture technique serves as a research tool for gaining a deeper understanding of participants' thought processes and personal experiences. This technique is particularly useful in situations where language or writing skills are limited. It serves as an alternative based on emotional and economic considerations, and can reveal nuances that other research methods cannot capture (Haney et al., 2004; Hsieh & Tsai, 2017). Besides, the draw-a-picture technique can guide learners to express their opinions freely and to demonstrate their cognitive structure through free drawings, texts, symbols and visual expressions, so that researchers can understand their perceptions (Chang & Tsai, 2023; Liou, 2017; Yeh et al., 2019). For example, Zhang et al. (2023) used the draw-a-picture technique to analyze elementary school students' stereotypes about robots. Barak et al. (2023) employed multiple dimensions to explore teachers' understanding of nature of science, which included focus – the central image/s (i.e., the central element or main message of the image), details – the particulars in each image (i.e., each single element in the image or specific details in the image), interactions – the links between images (i.e., relationships or connections between the images), context – the drawing setting (i.e., the broader situation or context of the image, including time, place, or other elements relevant to the topic), and written explanation.

In addition, questionnaires, interviews, and experiments are the most commonly used methods in the field of educational research to understand learners' learning perceptions, attitudes, and experiences (Chang et al., 2022b; Liu et al., 2022). Nevertheless, even though these research methods have their own advantages, they also have certain limitations. For example, while questionnaires have the advantage of being structured and quantifiable, they may have difficulty capturing certain implicit or less quantifiable information. On the other hand, interviews can provide more layers and depth of data, but the implementation involves higher costs and time investment. The quality of the data may also be affected by the language ability of interviewees (Hsieh & Tsai, 2018; Tu et al., 2021). Some researchers have corroborated that understanding learners' multiple perspectives and conceptions of specific learning contexts can not only promote teachers to adjust their teaching strategies to better meet the needs of students, but can also enhance students' learning motivation and engagement (Chang et al., 2022b; Hwang et al., 2017; Vermunt & Vermetten, 2004). In addition, some scholars have employed the draw-a-picture technique to explore learners' perceptions of the use of emerging technologies (i.e., AI, smart technology, and the metaverse) in education, such as AI-assisted learning (Lai, 2021), smart healthcare technology contexts (Chang et al., 2022b), and the metaverse in higher education (Hwang et al., 2023).

Regarding students' conceptions of the roles and functionalities of ChatGPT in learning, it involves their inherent perceptions through exploration and actual experience of the ChatGPT-assisted learning process (Hwang & Chen, 2023; Tu et al., 2021). In order to gain a deeper understanding of participants' perceptions of and perspectives on the roles and functionalities of ChatGPT in learning, this study used the draw-a-picture technique. This allowed the participants to express their perspectives and opinions using images within the constraints of time and vocabulary, enabling the investigation of information that was difficult to measure (Chang & Tsai, 2023; Haney et al., 2004; Hsieh & Tsai, 2018).

3. Research questions

The research questions are listed as follows:

- What is the overall conceptual framework of undergraduates regarding the roles and functionalities of ChatGPT in learning? Are there differences in the conceptions (including roles, participants involved, locations, learning content, learning activities, objects, and emotions and attitudes) of the roles and functionalities of ChatGPT in learning of students with different growth mindsets?
- During the interaction between undergraduates and ChatGPT, are there differences in the interaction skills and question types of students with different growth mindsets?
- What are the information literacy and critical thinking tendencies of students with different growth mindsets?

4. Method

4.1. Participants

A total of 67 students from a university in northern Taiwan voluntarily joined the information literacy project which included search tools and retrieval techniques, Internet resource evaluation and utilization, and information quality assessment. Referring to the suggestions of previous research (Lo, 2023), this study incorporated the CLEAR framework for prompt engineering into information literacy learning activities as a guiding structure for students to interact with ChatGPT. As four of the students did not fully participate in the project, only 63 valid data were collected from 29 male and 34 female students, with an average age of 20.3 years. Each participating student had previous experience using ChatGPT. The Research Ethics Committee from the institution with which the study is affiliated granted ethical approval. Participants were also advised that they were free to discontinue their involvement in the study at any time without any negative consequences.

4.2. Data collection and instruments

In order to deeply understand the differences in the learning effectiveness of learners with different growth mindsets, a growth mindset questionnaire was administered before the learning activities. Afterwards, the students were required to complete four tasks, that is, taking an information literacy test (ILT), filling out a critical thinking tendency questionnaire, drawing their perceptions of ChatGPT-supported learning activities, as well as completing a learning sheet with the assistance of ChatGPT.

The questionnaire assessing growth mindset was adapted from the original instrument developed by Bai et al. (2019). This modified version incorporated three items, that is, “I learned a lot of knowledge and skills when using ChatGPT from this project,” “I hope to learn how to use ChatGPT to challenge my information literacy in this project,” and “I believe that putting in more effort can improve my information literacy.” The questionnaire adopted a 5-point Likert scale (5 = *strongly agree*; 1 = *strongly disagree*). The Cronbach’s alpha value of the original scale was .75.

The ILT was modified from Boh Podgornik’s et al. (2015) ILT for higher education. The test design and content included information sources and databases, search strategies, intellectual property and ethics, and heuristics and critical evaluation. It consisted of 40 multiple-choice items, with a perfect score of 100. The reliability of the ILT in Šorgo’s et al. (2017) study was .71, calculated with a Cronbach’s alpha value. The ILT test paper was reviewed and modified by two library and information science professors with more than 5 years of teaching experience.

The critical thinking tendency questionnaire was modified from Chai et al. (2015). It consisted of six items, for example, “I will reflect on whether the knowledge I have learned through ChatGPT is accurate,” “I will judge the value of new information or evidence provided by ChatGPT in the learning activities,” and “In the learning activities, I will try to understand the information provided by ChatGPT from different perspectives.” The questionnaire adopted a 5-point Likert scale (5 = *strongly agree*; 1 = *strongly disagree*). The Cronbach’s alpha value was .80, showing adequate reliability.

Finally, the students were mandated to complete two principal activities: drawing a picture and completing a learning sheet with the assistance of ChatGPT. They were made to create a painting on A4 paper to demonstrate their conceptions of the roles and functionalities of ChatGPT in learning (Haney et al., 2004; Lai, 2021). In order

to deeply understand how the students perceived the ChatGPT-facilitated learning context, a specific prompt was provided, “According to your comprehension and experience of using ChatGPT, please draw a picture to describe your perspectives regarding the roles and functionalities of ChatGPT in learning.” The students were encouraged to express their conceptions in any way (including symbols, text, concept maps, and other creative forms). Moreover, they were asked to write down three to five short sentences to describe their drawings. As for the learning sheet, the students were required to submit their communication/interaction content with ChatGPT, so as to understand how they utilized this tool to support learning. Among 67 students, the data of four students were invalid because they did not complete the drawing and related learning activities. Thus, a total of 63 valid questionnaires, drawings, and learning sheets were collected as the data to understand students’ conceptions and situations of using ChatGPT for learning from different perspectives.

4.3. Coding scheme

This study employed the draw-a-picture technique to explore undergraduates’ conceptions of the roles and functionalities of ChatGPT in learning. Referring to previous scholars, such as Haney et al. (2004) and Hsieh and Tsai (2018), a coding scheme for drawings was developed, consisting of the seven categories of roles, participants involved, locations, learning content, learning activities, objects, and emotions and attitudes (see Table 1). It’s important to highlight that each drawing wasn’t confined to a single category; that is to say, an individual drawing could display various characteristics. However, recurring instances of the same subcategory within a single drawing were tallied only once for analysis. Figure 1 shows the coding of a HGM student’s drawing. It demonstrated that through the personal computer and mobile phone, a learner happily consulted/discussed some information and completed assignments with ChatGPT, and used it for translation and English learning.

Table 1. The coding scheme developed from students’ drawings

Categories	Subcategories			
1. Roles	1.1	Tutee	1.3	Tools
	1.2	Tutor		
2. Participants involved	2.1	Teachers	2.3	Robot
	2.2	Learners	2.4	No human drawn
3. Locations	3.1	Home	3.3	Unspecified
	3.2	In-class activities		
4. Learning content	4.1	Specific learning content	4.2	Non-specified
5. Learning activities	5.1	Search information	5.3	Discussions and consultations
	5.2	Reports/assignments	5.4	Translation
6. Objects	6.1	Personal computer (PC) / Notebook (NB)	6.5	Tables and chairs
			6.6	Traditional classroom equipment
	6.2	Tablet		
	6.3	Mobile phone	6.7	Others
	6.4	Books		
7. Emotions and attitudes	7.1	Positive	7.3	No use of affective words or symbols
	7.2	Negative		

In order to obtain a comprehensive understanding of the different communication ways when the undergraduates were using ChatGPT, including interaction skills (e.g., role-play, styles, polite responses, be specific, and output formatting) and question types, this study referred to previous studies (i.e., Hwang & Chen, 2023; Lo, 2023) to develop a coding scheme to analyze their interaction with ChatGPT. The same subcategory that appeared in the same conversation was counted only once. Table 2 shows the detailed coding scheme.

In addition, to ensure the accuracy and appropriateness of the coding schemes in Table 1 and Table 2, two senior experts from the field of technology-assisted learning were invited to assess and revise the coding scheme, which included all elements of the student drawings. Two independent coders coded the drawings according to the coding scheme with a Cohen’s kappa value of .83 (Lavrakas, 2008), showing a high level of agreement on the coding results. Besides, inconsistent coding was discussed by the experts to reach a consensus.

Figure 1. An example of the coding of a participant's drawing

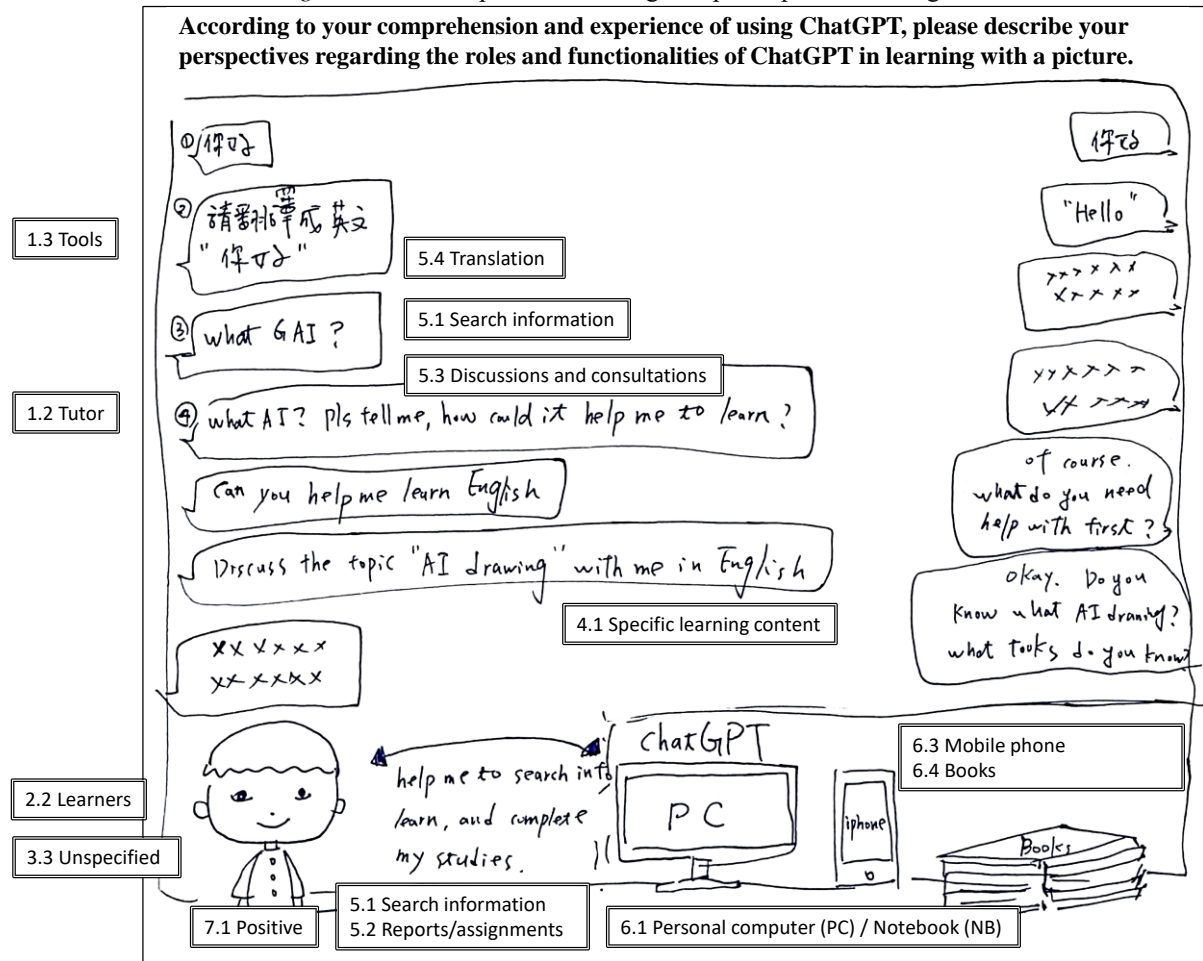


Table 2. The coding scheme developed from students' interaction skills and question types with ChatGPT

Categories	Subcategories	Description
Interaction skills	Role-play	When interacting with ChatGPT, students may play a specific role to better simulate specific situations or emotional reactions, such as asking ChatGPT to act as a digital learning expert.
	Styles	The language style or writing style used in the communication process, such as formal, informal, colloquial, etc.
	Polite responses	Polite responses to ChatGPT, such as expressing gratitude after obtaining the necessary information or completing a task.
	Be specific	When using ChatGPT to perform a certain task, the task is clearly and specifically defined and described for students to achieve the goal more accurately.
	Output formatting	The format of information output requested by students to ChatGPT, such as specific document types, formatting requirements, etc.
Question types	Test questions	There is one or one set of correct answers. The answers to the questions (e.g., What is information literacy?) can often be found in relevant books or textbooks.
	Authentic questions	Uptake questions: Uptake means that a person's question is related to a previous conversation. Uptake questions should be relevant to the ongoing conversation and can be directed towards an individual or the entire group, for example, "Based on your previous response, could you please explain the second point in more detail?" Higher-level thinking questions include speculation questions, generalization questions, and analysis questions, for instance,

Exploratory talk	<p>“Given what we’ve just said about a and b, what’s your viewpoint?”</p> <p>Exploratory talk takes place when learners share, evaluate and build knowledge. Learners reason, challenge, and respond to challenge with reasons and evidence, for example, “Based on your answer, I disagree with the first point. Could you please explain why you think so?”</p>
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4.4. Data analysis

This study adopted a mixed methods approach, incorporating quantitative and qualitative research methods. First of all, referring to Hwang et al. (2023), this study used the mean score of the growth mindset questionnaire to determine the high growth mindset group (HGM group) and the low growth mindset group (LGM group). On this basis, the independent *t* test was used to analyze the data of learning achievement (i.e., ILT) and critical thinking tendency, so as to explore the differences between students with different growth mindsets.

Furthermore, to explore the perceptions of students with different growth mindsets regarding the roles and functionalities of ChatGPT in learning, this study systematically coded students’ drawing and performed a Chi-square test to report the differences in each category. This revealed students’ diverse and complex conceptions and attitudes towards the roles and functionalities of ChatGPT in learning. Also, this study coded and analyzed the interaction content between students and ChatGPT, with a particular emphasis on interaction skills and question types. Through this series of in-depth analysis, this study expected to achieve a more comprehensive and in-depth understanding of students’ conceptions and practices regarding the roles and functionalities of ChatGPT in learning.

5. Results

5.1. Undergraduates’ conceptions of roles and functionalities of ChatGPT in learning

As delineated in Table 1, the drawings submitted by 63 undergraduates were subjected to analysis. The coding process yielded a cumulative total of 714 codes. Of these, 386 codes were attributed to students categorized in the HGM and 328 group to those in the LGM group. Table 3 shows the results of the item frequency and percentage of students’ drawings. Overall, in terms of their conceptions of the roles and functionalities of ChatGPT in learning, the most to least drawn categories were learning activities (29.13%), objects (18.07%), roles of ChatGPT (16.53%), participants involved (9.80%), locations (8.82%), learning content (8.82%), and emotions and attitudes (8.82%). This implied that, for the majority of students, the roles and functionalities of ChatGPT in learning involved learning activities (i.e., reports/assignments, search information, and discussions and consultations), objects (i.e., PC/NB, mobile phone, and tablet), roles of ChatGPT (i.e., tools and tutor), and participants involved (i.e., learners, no human drawn, teachers, or robots).

As shown in Table 3, when the undergraduates were asked to describe their conceptions and experience regarding the roles and functionalities of ChatGPT in learning, most of them viewed ChatGPT as learning “tools” or media. To be more specific, students in both the HGM group and the LGM group believed that ChatGPT could play the role of a tool in the learning process. Besides, in comparison with those in the LGM group, students in the HGM group were significantly more inclined to regard ChatGPT as a “tutor” ($\chi^2 = 16.91, p < .001$). This implied that both groups shared a common understanding of viewing ChatGPT as a learning tool or medium. However, there was a significant difference between the two groups in terms of ChatGPT as a tutor. In particular, the LGM group did not think of ChatGPT as a “tutee” when using ChatGPT for learning.

Concerning the “participants involved” category, students most frequently drew “learners,” followed by “no human drawn,” “teachers,” and “robots.” There was no significant Chi-square difference in this category between the drawings of students in both groups ($\chi^2 = 6.02, p > .05$). This indicated that they shared common conceptions; that is, the conceptions of students in both the HGM group and the LGM group involved learners.

As shown in Table 3, in the “locations” category, students from the HGM group most frequently drew “unspecified,” followed by “in-class activities.” On the other hand, students from the LGM group most frequently drew “unspecified,” followed by “in-class activities” and “home.” There was a significant Chi-square difference in this category between the two groups ($\chi^2 = 8.92, p < .05$). In comparison with the LGM group, the

HGM group was significantly more inclined to draw “unspecified” locations when describing the roles and functionalities of ChatGPT in learning ($\chi^2 = 18.79, p < .001$). In contrast, in comparison with those in the HGM group, more students in the LGM group focused on “home” ($\chi^2 = 9.46, p < .01$) and “in-class activities” ($\chi^2 = 6.61, p < .05$) when describing the role and functionalities of ChatGPT in learning.

Table 3. Distribution of perceptions of undergraduates regarding the roles and functionalities of ChatGPT in learning by the categories and subcategories

Categories and subcategories	HGM students <i>N</i> (% = <i>N</i> /32)	LGM students <i>N</i> (% = <i>N</i> /31)
Roles		
Tutor	32 (100%)¹	18 (58.06%)²
Tutee	5 (15.63%)²	0 (0%)
Tools	32 (100%)¹	31 (100%)¹
Participants involved		
Teachers	1 (3.13%)³	3 (9.68%)³
Learners	29 (90.63%)¹	24 (77.42%)¹
Robots	3 (9.38%)²	0 (0%)
No human drawn	3 (9.38%)²	7 (22.58%)²
Locations		
Home	0 (0%)	8 (25.81%)²
In-class activities	1 (3.13%)²	8 (25.81%)²
Unspecified	31 (96.88%)¹	15 (48.39%)¹
Learning content		
Specific learning content	21 (65.63%)¹	8 (25.81%)²
Non-specified	11 (34.38%)²	23 (74.19%)¹
Learning activities		
Search information	32 (100%)¹	29 (93.55%)²
Reports/assignments	32 (100%)¹	31 (100%)¹
Discussions and consultations	30 (93.75%)²	24 (77.42%)³
Translation	25 (78.13%)³	5 (16.13%)
Objects		
PC/NB	32 (100%)¹	24 (77.42%)¹
Tablet	11 (34.38%)³	8 (25.81%)³
Mobile phone	12 (37.50%)²	11 (35.48%)²
Books	7 (21.88%)	7 (22.58%)
Tables and chairs	1 (3.13%)	6 (19.35%)
Traditional classroom equipment	1 (3.13%)	7 (22.58%)
Others	2 (6.25%)	0 (0%)
Emotions and attitudes		
Positive	22 (68.75%)¹	23 (74.19%)¹
Negative	0 (0%)	0 (0%)
No use of affective words or symbols	10 (31.25%)²	8 (25.81%)²

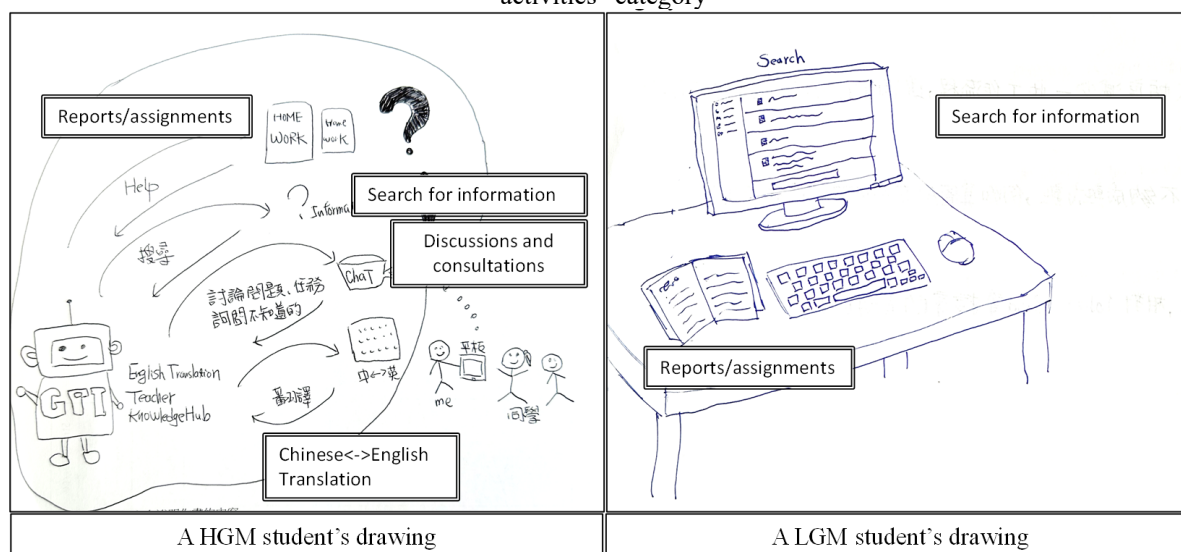
Note. The top three subcategories are marked in bold face, and the superscript denotes ranking within each category.

In addition, a significant difference existed in the “learning content” of the drawings between the HGM group and the LGM group according to the Chi-square analysis ($\chi^2 = 10.05, p < .01$). In comparison with those of the LGM group, “specific learning content” appeared more frequently in the drawings of the HGM group ($\chi^2 = 10.05, p < .01$, see Figure 1). On the other hand, in comparison with those in the HGM group, more students in the LGM group focused on “non-specified” learning content ($\chi^2 = 10.05, p < .01$, see Figure 2).

Figure 2 illustrates sample drawings of students in the LGM group and the HGM group. As for the “learning activities” category, students mostly drew “reports/assignments,” followed by “search information,” “discussions and consultations,” and “translation.” The Chi-square test uncovered a significant difference in this category between the HGM group and the LGM group ($\chi^2 = 10.05, p < .01$). In comparison with those of the LGM group, “translation” appeared more frequently in the drawings of the HGM group ($\chi^2 = 24.26, p < .05$). Nonetheless, there were significant differences between the two groups in the subcategories of “reports/assignments,” “search information” and “discussions and consultations.” This implied that among the conceptions of the roles and functionalities of ChatGPT in learning of the two groups, “reports/assignments,” “search information” and “discussions and consultations” were the most frequently drawn learning activities; yet, a significant difference

was observed in the subcategory of “translation.” In the drawing of the LGM student, ChatGPT was described as a tool used to search for information and to assist with assignments (see Figure 2).

Figure 2. Examples of the “reports/assignments” and “search for information” subcategories in the “learning activities” category



As shown in Table 3, in the “objects” category, the most common object drawn by students was “PC/NB,” followed by “mobile phone,” “tablet,” “books,” “traditional classroom equipment,” “tables and chairs,” and “others.” There was no significant difference in this category between the two groups according to the Chi-square test ($\chi^2 = 11.67, p > .05$). This implied that the HGM group and the LGM group shared common conceptions of the roles and functionalities of ChatGPT in learning in terms of “object.”

As for the “emotions and attitudes” category, students often mostly drew “positive,” followed by “unspecified.” It is worth noting that the students did not display any negative emotions or attitudes in their drawings. There was no statistically significant disparity in this category among the drawings produced by students with different growth mindsets ($\chi^2 = 0.22, p > .05$). This specified that the undergraduates held similar emotions and attitudes regarding the roles and functionalities of ChatGPT in learning; they mainly expressed positive emotions and attitudes in their drawings.

5.2. Undergraduates’ interaction skills and question types with ChatGPT

Utilizing the coding scheme shown in Table 2, the interaction skills and question types of 63 undergraduates with ChatGPT were analyzed. Table 4 displays the occurrence and percentage distribution of the item in the students’ drawings. In terms of interaction skills, the most to least applied skills were “role-play,” “be specific,” “styles,” “output formatting,” and “polite responses.” In comparison with the LGM group, the HGM group adopted “role-play,” “be specific,” “output formatting,” “styles,” and “polite responses” more frequently, and the results showed significant Chi-square differences in these subcategories ($\chi^2 = 16.28, p < .01$). This implied that the HGM group demonstrated more diverse and professional skills when interacting with ChatGPT.

As for question types, both groups of students most frequently employed “test questions,” followed by “authentic questions” and “exploratory talk.” A significant Chi-square difference existed in this category between the two groups ($\chi^2 = 14.64, p < .01$). Also, there was a significant Chi-square difference in the subcategory of “authentic questions” between the HGM group and the LGM group ($\chi^2 = 14.64, p < .01$). This revealed that the HGM group demonstrated question-posing and higher-level abilities when interacting with ChatGPT. They might be better at using questions to explore, analyze, and reflect on knowledge rather than merely to assess and confirm.

Figure 3(a), (b) and (c) demonstrate the coding of the interaction between a student from the HGM group and ChatGPT. First of all, the student posed a specific question, “Does information literacy refer to a person’s ability to use information technologies?” and requested that ChatGPT act as an undergraduate (i.e., role-play) to answer the question. Then, the student asked further questions based on ChatGPT’s answers (see Figure 3(a)). Figure 3(b) further shows that the student politely expressed gratitude and asked ChatGPT to provide the answers in a

table. Afterwards, ChatGPT was requested to rewrite the content in an interesting style. Figure 3(c) illustrates that the student posed a higher-level thinking question, “A learner asks ChatGPT when he has a problem, and he learns from the content provided by ChatGPT. Is ChatGPT a learning tool and tutor in this case?” Regarding this question, the student also questioned and challenged ChatGPT’s responses.

Table 4. Distribution of interaction skills and question types between undergraduates and ChatGPT by the categories and subcategories

Categories	Subcategories	HGM students <i>N</i> (% = <i>N</i> /32)	LGM students <i>N</i> (% = <i>N</i> /31)
Interaction skills	Role-play	32 (100%)¹	26 (83.87%)¹
	Styles	28 (87.50%)²	11 (35.48%)³
	Polite responses	9 (28.13%)³	1 (3.23%)
	Be specific	32 (100%)¹	18 (58.06%)²
	Output formatting	32 (100%)¹	3 (9.68%)
Question types	Test questions	32 (100%)¹	31 (100%)¹
	Authentic questions	32 (100%)¹	18 (58.06%)²
	Uptake questions	32 (100%)¹	18 (58.06%)²
	High-level thinking questions	14 (43.75%) ³	0 (0%)
	Exploratory talk	4 (12.50%)	0 (0%)

Note. The top three subcategories are marked in bold face, and the superscript denotes ranking within each category.

Figure 3(a). An example of the coding for interaction skills and question types in a HGM student’s conversation with ChatGPT

U Does information literacy refer to a person's ability to use information technologies?

- Test questions
- Be specific

ChatGPT Information literacy goes beyond just the ability to use information technologies. It encompasses a broader set of skills that enable individuals to effectively locate, evaluate, use, and communicate information in various formats and from different sources. While information technologies play a role in facilitating these skills, information literacy involves a deeper understanding of how to navigate the vast sea of information available in the digital

U As a university student, I now ask for your advice on the question I posed. My question is Do you think chatGPT is relevant to students' information literacy abilities?

- Role-play
- Be specific

ChatGPT Certainly, exploring the relevance of ChatGPT to students' information literacy abilities is an intriguing question, and I'd be glad to provide you with a detailed analysis.

ChatGPT, as an AI language model, has the potential to impact students' information literacy in both positive and challenging ways. Here's a breakdown of the key points:

Positive Aspects:

- 1. Access to Information:** ChatGPT can serve as a powerful tool for students to access a vast amount of information on various topics. It can assist in quickly retrieving information from diverse sources, aiding students in their research and coursework.

U Thank you. In response to the part of the question that promotes critical thinking, for example, "Students are encouraged to use the ChatGPT as a starting point for exploration, rather than as a definitive source of information. This approach develops critical thinking skills and motivates further research." Could you possibly explain this? Could you please provide me with an example so that I could understand more about this topic.

- Polite responses
- Uptake questions
- Be specific

ChatGPT Certainly, I'd be glad to elaborate on the concept of using ChatGPT as a starting point for exploration and provide an example to illustrate its application.

When students are encouraged to use ChatGPT as a starting point for exploration rather than a definitive source, the goal is to foster their critical thinking skills and motivate them to engage in deeper research. Here's how this approach works:

- 1. Initial Engagement:** Imagine a student is researching the impact of climate change on marine ecosystems. They turn to ChatGPT and ask, "What are the effects of climate change on marine life?" ChatGPT provides a concise overview of some effects.

Figure 3(b). An example of the “output formatting,” “polite responses,” “styles,” and “be specific” subcategories in a HGM student’s conversation with ChatGPT

User: Could you describe the role of the chatgpt-assisted learner from the perspective of a tool, a tutor, and a tutee? Please provide a table with columns for "Role", "Description", "Example", and "Notes".

ChatGPT: Certainly, I'd be happy to describe the role of a ChatGPT-assisted learner from the perspectives of a tool, a tutor, and a tutee. Here's a table summarizing these roles:

Role	Description	Example	Notes
Tool	In the role of a tool, the ChatGPT-assisted learner uses AI-generated content to	A student uses ChatGPT to quickly summarize a lengthy research paper.	Learners should recognize ChatGPT as a tool that provides information but

User: Thank you. Based on the table, could you please rewrite the content in an interesting style?

ChatGPT: Of course! Here's the table with columns for "Role," "Description," "Example," and "Notes," just as you requested:

Role	Description	Example	Notes
Explorer	Our learner becomes an intrepid explorer, armed with ChatGPT as their digital	Like a modern-day adventurer, our learner queries ChatGPT to distill	While ChatGPT guides exploration, critical thinking is vital to

Annotations:

- Output formatting
- Be specific
- Polite responses
- Styles
- Be specific

Figure 3(c). An example of the “output formatting,” “polite responses,” “styles,” and “be specific” subcategories in a HGM student’s conversation with ChatGPT

User: Thank you, I need you to answer the following questions. "A learner asks ChatGPT when he has a problem, he learns from the content provided by ChatGPT, is ChatGPT a learning tool and tutor in this case? Please explain.

ChatGPT: Indeed, in the scenario you've presented, where a learner interacts with ChatGPT to seek solutions to problems and learns from the content provided, ChatGPT can indeed be considered both a learning tool and a tutor. Let's delve into the explanation:

Learning Tool:
In this context, ChatGPT functions as a learning tool by providing the learner with information, explanations, and insights that contribute to their understanding of a particular

User: Thank you for answering the question. However, I disagree with the following, I think the role of ChatGPT in the learning process affects the effectiveness of the learning process, can you explain more about your point of view? "When learners interact with ChatGPT to solve problems and learn from the information provided, they experience a double benefit. As a learning tool, ChatGPT is a fountain of knowledge, providing insights that broaden learners' perspectives and contribute to their overall understanding. As a tutor, ChatGPT acts as a guide, providing explanations, clarifications and guidance, which is in line with the classic tutoring process of scaffolding learning through interaction".

ChatGPT: I appreciate your perspective, and I'd be glad to provide a more nuanced explanation. You're absolutely right that the role of ChatGPT in the learning process significantly influences its effectiveness. Let's delve into this viewpoint:

1. Learning Tool Impact:
While ChatGPT can indeed provide a wealth of information and insights, the effectiveness of

Annotations:

- Polite responses
- High-level thinking questions
- Be specific
- Polite responses
- High-level thinking questions
- Exploratory talk
- Be specific

5.3. Learning achievement and critical thinking tendency

Table 5 shows the independent sample *t*-test results of learning achievement and critical thinking tendency of the two groups. In terms of learning achievement, the mean score and standard deviation of the HGM group were 88.98 and 2.97, while those of the LGM group were 81.13 and 3.22. The *t*-test results ($t = 10.08$, $p < .001$)

disclosed that the HGM group significantly outperformed the LGM group, with a large effect size ($d = 2.54$) (Cohen, 1988). As for critical thinking tendency, the mean score and standard deviation of the HGM group were 4.54 and 0.28, while those of the LGM group were 3.75 and 0.34. The t -test results ($t = 9.948$, $p < .001$) revealed that the HGM group had significantly better critical thinking tendency than the LGM group, with a large effect size ($d = 2.51$) (Cohen, 1988).

Table 5. t-test results

Variable	Group	<i>N</i>	Mean	<i>SD</i>	<i>t</i>	<i>d</i>
Learning achievement	HGM group	32	88.98	2.97	10.08***	2.54
	LGM group	31	81.13	3.22		
Critical thinking tendency	HGM group	32	4.54	0.28	9.948***	2.51
	LGM group	31	3.75	0.34		

Note. *** $p < .001$.

6. Discussion and conclusions

6.1. Discussion

This study compared the viewpoints of students with different growth mindsets regarding the roles and functionalities of ChatGPT in learning through drawing. Even though the two groups of students shared similar conceptions in terms of “roles,” “participants involved,” “objects,” and “emotions and attitudes,” significant differences were found in “locations,” “learning content” and “learning activities.” During the interaction with ChatGPT, there were significant differences in interaction skills and question types between students with different growth mindsets. This study also analyzed the differences in learning achievement, and critical thinking tendency between students with different growth mindsets. The findings not only revealed the conceptions, attitudes, interaction skills, learning achievement, and critical thinking tendency of students with different growth mindsets regarding the roles and functionalities of ChatGPT in learning, but also provided insights into how to more effectively integrate ChatGPT into learning activities.

Regarding the first research question, the results uncovered that when the undergraduates were prompted to describe the roles and functionalities of ChatGPT in learning, most of them focused on “learners” themselves. They viewed ChatGPT as a learning tool and tutor, and employed mobile devices (e.g., NB, mobile phone, and tablet) to engage in learning activities without a specific location. These activities included “reports/assignments,” “search for information,” and “discussions and consultations,” and can be incorporated with specified or non-specified learning content. The students also demonstrated positive emotions and attitudes in the learning process. This indicated that most undergraduates regarded ChatGPT as a personalized learning tool and tutor, thus highlighting the importance of independent learning. This might also be related to their understanding of existing educational tools and teaching approaches. Besides, students could learn through mobile devices without the restraint of location. This flexible and adaptable learning mode allowed ChatGPT to be combined with specified or non-specified learning content, thus underscoring the application potential of ChatGPT in different disciplines and topics. Chan (2023) reported that neither students nor teachers believed that AI would replace teachers in the future. She suggested that teachers and students required a balanced approach/mechanism to adopt AI technology, and that AI should be used as a complementary teaching approach rather than an alternative one. Similarly, some studies have pinpointed that when students encounter challenges in learning tasks, GAI technology (e.g., ChatGPT) can act as a virtual tutor to provide immediate and personalized learning support, thereby promoting learners’ cognitive development and understanding (Chan & Hu, 2023). As indicated in previous research, ChatGPT can help students engage in individual learning, and further enhance their learning experience by providing personalized and interactive support (Berdanier & Alley, 2023; Cooper, 2023; Firat, 2023; Hwang & Chen, 2023). Furthermore, some researchers have also emphasized the importance of different roles such as tutors, tutees, and tools to contribute to the educational process in technology-enhanced environments (Hwang & Chien, 2022; Lai, 2021).

Based on the coding results, significant differences existed in the categories of “locations,” “learning content,” and “learning activities” between students with different growth mindsets. In the “locations” category, most of the undergraduates, especially those in the HGM group, did not specify a location in their drawings. Also, in comparison with those in the HGM group, students in the LGM group were significantly more inclined to adopt ChatGPT at “home” and during “in-class activities” to facilitate their learning. This suggested that the HGM group might pay more attention to the learning process and outcomes rather than specific learning locations. On the other hand, the LGM group tended to learn in familiar and comfortable environments (e.g., homes and

classrooms) rather than broader or diverse learning venues (Liu et al., 2022). As for the “learning content” category, students with different growth mindsets demonstrated different learning trends. Students in the HGM group were inclined to adopt ChatGPT for “specified” learning content, reflecting their goal orientation and focus; they might regard ChatGPT as a tool to achieve specific learning goals. In contrast, students in the LGM group utilized ChatGPT for “non-specified” learning content, which illustrated their openness to exploring various topics. Yu et al. (2022) pointed out that in a learning environment that employed the guided inquiry approach and focused on students’ social-emotional development, students tended to recognize their growth mindsets. For instance, teachers could provide students in the HGM group with more challenging tasks for them to delve into specific topics. On the other hand, students in the LGM group might need more guidance and support to focus their exploration on specific learning goals, so as to build confidence and promote active learning experience. Finally, in the “learning activities” category, both groups shared similar conceptions in terms of “reports/assignments,” “search information,” and “discussions and consultations.” It is worth noting that the “translation” subcategory appeared more frequently in the drawings of the HGM group in comparison with those of the LGM group. The results disclosed that although the two groups had similar conceptions in most learning activities, a significant difference in “translation” could be found. This might be closely related to the design mechanism of learning activities, which had the potential to shape and influence students’ cognitive structures and conceptual models. In addition, this finding also implied that the HGM group engaged in more diverse learning activities when using ChatGPT to assist their learning (Tewell, 2020; Tseng et al., 2020).

As for the second research question, this study analyzed the interaction skills and question types between the undergraduates and ChatGPT. The results indicated significant differences in these two categories between the HGM group and the LGM group. Table 4 shows that the HGM group performed more diverse interaction skills (i.e., “role-play,” “be specific,” “styles,” “output formatting,” and “polite responses”) than the LGM group. This might be because students with a high growth mindset generally had a more positive and proactive attitude toward learning; they were more inclined to explore and challenge themselves so that they could perform richer and more diverse interaction skills from different angles and perspectives. The results implied that students in the HGM group were more goal-oriented, attentive, and proficient in inquiry and critical thinking during the learning process, and they were also more effective in using ChatGPT as a learning tool. With regard to the “question types” category, “test questions” were commonly used by both groups, probably because this was the basic way of learning and understanding knowledge. Also, the HGM group mainly used “uptake questions” in the “authentic questions” subcategory. On the other hand, the two groups seldom used “higher-level thinking questions” and “exploratory talk.” In particular, both groups rarely employed “exploratory talk.” This pointed out that the undergraduates were less likely to actively put forward their own opinions or evidence during the interaction process, and that they seldom questioned or challenged the content provided by ChatGPT during the conversation. Previous research has pinpointed that putting emphasis on specific conceptions or questions during the training phase has the potential to shape and guide learners’ cognitive structures and thinking patterns (Yan, 2023). Based on this finding, instructional design should comprehensively consider learners’ knowledge and skill gaps in relevant fields, and adopt corresponding teaching strategies to further strengthen their knowledge and skills in exploratory talk. As mentioned by Hwang and Chen (2023), to effectively utilize GAI in the field of education, two key conceptions should be understood and realized. The first is “knowing why,” which is a key element to foster learners’ in-depth understanding. The second is the conception of “It’s all about prompts,” which abandons the traditional search mindset and employs the programming prompt instead.

With regard to the third research question, the HGM group had significantly higher learning achievement (i.e., ILT) and critical thinking tendency than the LGM group. These findings were in line with previous studies, indicating that students with a high growth mindset are usually more open and motivated to learn and explore new knowledge. This may prompt them to believe that abilities can be improved through hard work, thereby enhancing their learning motivation and achievement (Dweck, 2006; Hwang et al., 2023; Lai & Hwang, 2014). Students with a high growth mindset may tend to analyze and evaluate information and be more willing to engage in critical thinking, thus improving their learning motivation (Liu et al., 2022). This was in accordance with the findings of the second research question, highlighting the critical thinking and analytical abilities of the HGM group. They asked questions to facilitate deeper understanding through active exploration, analysis and reflection, which underscored their active learning attitudes and pursuit of mastery of knowledge. Furthermore, appropriate learning tools and teaching strategies could increase students’ willingness to learn and alleviate their negative emotions during the information search process (Guo et al., 2015). The positive correlations between high growth mindsets and motivation, learning achievement and critical thinking tendency seemed intuitive; however, they might involve quite complex interaction and influencing factors (Miller & Srougi, 2021), which requires further research to enhance understanding. In addition, several studies have specified the importance of critical thinking and have recommended its integration into instructional design and the evaluation of learning effectiveness. This can prompt students not only to accept information, but also to effectively deconstruct and analyze it. Also, digital literacy and information literacy are regarded as a core interdisciplinary competence,

which involves the retrieval, verification and application of information in online and physical environments (Chan, 2023; Lo, 2023; Lai & Hwang, 2014; Lund & Agbaji, 2023).

6.2. Research limitations and recommendations

This study has some limitations. First, this information literacy project only lasted 6 hours, and the data were collected from undergraduates at a single university; therefore, generalizability is limited, and the results may not represent all undergraduates in Taiwan. Second, this study adopted questionnaires to evaluate undergraduates' growth mindsets and critical thinking tendency, while other aspects (e.g., learning motivation, cognitive load, and learning anxiety) were not investigated. Third, this study utilized the draw-a-picture technique as the principal method for data collection, aiming to investigate the conceptions held by students with different growth mindsets regarding the roles and functionalities of ChatGPT in learning. Students' drawings were coded into seven categories (i.e., roles, participants involved, locations, learning content, learning activities, objects, and emotions and attitudes). However, further research is needed to better understand how to accommodate the needs of students with different growth mindsets. To gain a more comprehensive understanding, it is recommended that future research broaden the scope of investigation to include schools at different grade levels and a larger number of undergraduates. In addition, a combination of questionnaires, interviews and behavioral analysis can be adopted to understand learners' conceptions of the roles and functionalities of ChatGPT in learning, as well as their interaction with ChatGPT from multiple perspectives. Based on the findings, the following recommendations were made for future studies:

- It is recommended that future studies incorporate teaching strategies to explore the changes in quality and learning effectiveness at different time intervals. In addition, future research can further investigate the conceptions and perceptions of students at different educational stages (e.g., elementary school, high school, university, and graduate school) regarding the roles and functionalities of ChatGPT in learning, as well as their behavioral characteristics when using ChatGPT in learning.
- Future research is recommended to adopt multiple research methods (e.g., interviews, and behavioral analysis) and interdisciplinary empirical research, as well as to explore the effects of ChatGPT-integrated learning activities on students' learning motivation, cognitive load, learning anxiety and higher-level thinking skills.
- In order to promote students' higher-level thinking skills, it is recommended to include learning activities involving practical challenges and projects in the instructional design. Additionally, it is recommended that future studies continue to evaluate students' interaction with ChatGPT, so as to gain insights into how the interaction impacts their higher-level thinking skills.
- In order to enhance students' learning effectiveness and problem-solving ability in ChatGPT-assisted learning, it is recommended to incorporate learning strategies for active engagement and problem solving (e.g., computers as Mindtools, project-based learning, and inquiry-based learning). Moreover, future research can further explore the correlation between growth mindset and self-regulated learning, and delve into the effects of some variables (e.g., learning strategies, self-regulated learning) on learners' effectiveness in using ChatGPT to assist learning.
- It is recommended that future research delve into the influences of ChatGPT's role as teacher/tutor, student/tutee, learning peer/partner, domain expert, administrator, and learning tool in learning activities on students' knowledge and abilities, for instance, exploring students' acceptance and feedback on different roles of ChatGPT and evaluating how different roles can improve learning effects.

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Facilitating nursing and health education by incorporating ChatGPT into learning designs

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ABSTRACT: Traditional nursing and health education design courses usually only transfer knowledge via lectures, and lack interaction, drills and personalized feedback. However, the development and widespread adoption of generative artificial intelligence via the ChatGPT system presents an opportunity to address these issues. Some CIDI model-based ChatGPT systems have been developed, but how to effectively apply these technologies in nursing education design courses remains a challenging problem for researchers. In order to explore the application mode and effect of generative artificial intelligence via ChatGPT technology in nursing education, this study integrated generative artificial intelligence via the ChatGPT system into the teaching activities of nursing and health education design courses, and used computers as learning tools to guide learners to learn nursing and health knowledge. At the same time, two classes of nursing undergraduates were recruited to conduct a quasi-experiment. One of the classes was the experimental group, which used the generative artificial intelligence via the ChatGPT system for learning; the other class was the control group, which used traditional teaching methods for learning. By analyzing learners' learning efficiency and learning satisfaction, we obtained results about the application effect of generative artificial intelligence via ChatGPT technology in a nursing education design course. According to the experimental results, the generative artificial intelligence via ChatGPT system effectively improved learners' critical thinking ability, problem solving, and learning enjoyment. These results indicate that the generative artificial intelligence via ChatGPT system has great potential in nursing education design courses, and can improve the deficiencies of traditional teaching methods.

Keywords: ChatGPT, Generative artificial intelligence via ChatGPT system, Nursing Training, Computer-assisted learning, Generative artificial intelligence in education

1. Introduction

Nursing health education is the most commonly used communication method for promoting health, providing the general public with essential knowledge about relevant diseases and preventive care (Bezerra, 2020; Maneejak & Yasri, 2020). Therefore, enhancing nursing learners' professional knowledge and skills in health education is especially crucial. Nursing health education design courses aim to comprehensively and systematically introduce various health knowledge topics; for example, hypertension dietary education courses can teach individuals proper daily eating habits and blood pressure monitoring to prevent stroke occurrences (Shi et al., 2022); stroke education courses can enhance stroke patients' home care and reduce the risk of recurrent strokes (Hu et al., 2022); and antenatal health education courses can effectively prepare pregnant women for childbirth and boost their confidence (Donkor et al., 2023).

The objective of health promotion courses is to cultivate learners' understanding of nursing health education design from both macro and micro perspectives, emphasizing effective and systematic planning. This equips nursing learners with the ability to integrate professional knowledge in their workplace and deliver accurate health information (Bezerra, 2020). Consequently, they can provide patients with the correct knowledge, thereby promoting self-care abilities and maintaining a good quality of life (Leutualy et al., 2021). Scholars indicate that nursing health education is the process of imparting fundamental nursing knowledge and skills to patients and their families (Donkor et al., 2023; Hu et al., 2022). Through carefully designed nursing health education, nursing learners learn how to effectively convey medical knowledge, disease prevention, and health promotion information, thereby enhancing the quality of patient care (Sharifzadeh et al., 2020).

In the context of nursing and health education, critical thinking involves evaluating, analyzing, and synthesizing information for informed clinical decisions, while problem solving entails applying critical thinking skills to

address complex healthcare challenges (Rahman, 2019). Learner enjoyment is crucial as it motivates active participation, enhancing retention and skill development (Batita & Wedi, 2023). Enjoyment in learning, while seemingly distinct, is pivotal for cultivating critical thinking and problem solving, enhancing motivation and information retention. Research, like Norman and Schmidt's (1992) study, indicates that enjoyable experiences can deepen understanding and improve problem solving in healthcare education. Scholars have also pointed out that strategies to boost enjoyment include creating a supportive environment and tailoring teaching methods to student preferences. Critical thinking and problem solving are vital in healthcare education. Traditional methods have limitations, but research suggests various pedagogical approaches to improve these skills and learner enjoyment (Zhang et al., 2023). A comprehensive approach integrating theory, practice, and active learning can enhance overall educational outcomes in healthcare education. Nowadays, in the era of globalization and advancements in information technology, innovative teaching methods have presented challenges to educators (Hwang & Chu, 2023; Tang et al., 2021). To cope with the emergence of new diseases and medical knowledge, it is necessary to involve learners in real-world problem-solving environments related to nursing health education design (Randhawa & Jackson, 2020). Based on the principles of problem-solving theory and adopting an active, hands-on approach to education, learners engage in real-life problem situations, analyze issues, and collaborate to find solutions (Reed, 2019). Reed (2019) emphasized that learning should be an inquiry and discovery process, rather than passive information absorption, to improve learners' learning outcomes. Problem solving also fosters critical thinking, creativity, and practical skills essential for active participation in society (Akinsanya & Ojotule, 2022; Luo, 2023). One of the fundamental competencies in clinical care is providing nursing health education after assessment and intervention. Regardless of their future specialization, nursing learners need to learn how to write nursing health education plans and deliver accurate health education before entering the workplace. Meanwhile, in order to immerse learners in real-life scenarios, traditional training adopts a teaching approach, assisting learners in understanding the significance of nursing health education for national health.

Researchers have suggested that one promising solution is to incorporate generative artificial intelligence through ChatGPT technologies into nursing training programs, providing personalized learning guidance and knowledge construction (Gunawan, 2023). Empirical studies have demonstrated the importance of technology in guiding learners to think critically, analyze problems, explore solutions, and seek additional information in learning tasks (e.g., Alkhateeb & Al-Duwairi, 2019; Araiza-Alba et al., 2021; Sahin & Yilmaz, 2020). Although integrating such emerging technology into curricula has been considered effective, learners often still require guidance from teachers rather than encouragement to explore, discover problems, and make decisions in problem-solving processes. To address this, scholars have attempted to use artificial intelligence technology to promote learners' autonomous learning and improve their learning outcomes (Tang et al., 2021). For instance, Huang and Qiao (2022) applied artificial intelligence education in high school STEAM courses to enhance learners' computational thinking skills. Additionally, Fauzi et al. (2023) utilized ChatGPT and generative language models in medical education at higher education levels, enabling learners to explore and learn through ChatGPT environments, resulting in more helpful information and resources, improved language skills, enhanced collaboration, increased time efficiency and effectiveness, and greater support and motivation.

As indicated by the above studies, educational technology researchers have been exploring how generative artificial intelligence via ChatGPT technologies can enhance teaching and learning effectiveness (Hwang & Chen, 2023). Concurrently, learners can connect the knowledge they acquire with real-world problems through the application of generative artificial intelligence via ChatGPT technologies (Gunawan, 2023). For most learners, nursing health education is a complex clinical task that requires the collection of clinical medical examination data, medical treatments, and patient health needs to provide appropriate health education messages, making it an important and challenging routine task in nursing practice (Hu et al., 2022; Donkor et al., 2023). To perform nursing health education effectively, nursing learners must learn how to prepare and assess professional health education knowledge and deliver it accurately (Donkor et al., 2023). Moreover, studies have identified that critical thinking, problem-solving, and enjoyment are pivotal in the learning and research process. A researcher who is intrinsically motivated and finds joy in the process is more inclined to engage profoundly, overcome challenges, and yield innovative results (Ryan & Deci, 2000). While critical thinking, problem solving, and enjoyment have each been examined separately, exploring their interconnectedness can offer fresh insights. However, this has not been extensively explored in the context of nursing health education. To address these training challenges, this study aimed to integrate generative artificial intelligence via a ChatGPT system into nursing health education design training courses, departing from traditional didactic teaching methods, and enhancing learners' learning outcomes. In this context, generative artificial intelligence via ChatGPT technologies refers to learners utilizing stored professional knowledge in a knowledge base to prompt and generate content within the system. Previous studies have demonstrated the potential of using generative artificial intelligence via ChatGPT technologies, specifically the CIDI model-based ChatGPT learning method,

for providing learning support or decision guidance to enhance learners' critical thinking, problem solving, and enjoyment. To assess the efficacy of this approach, we posed the following research questions:

- Was the critical thinking tendency of the students using the CIDI model-based ChatGPT learning method for nursing and health education significantly higher than that of those who learned with the conventional instruction?
- Was the problem solving of the students using the CIDI model-based ChatGPT learning method for nursing and health education significantly higher than that of those who learned with the conventional instruction?
- Was the learning enjoyment of the students using the CIDI model-based ChatGPT learning method for nursing and health education significantly higher than that of those who learned with the conventional instruction?

2. Relevant studies

2.1. Artificial intelligence for educational purposes

According to technology advances, Artificial Intelligence (AI) in education offers numerous benefits that can greatly enhance the learning experience for learners (Chen et al., 2020). Some of the key benefits of AI in education include personalized learning, adaptive learning, intelligent tutoring, enhanced assessment and feedback, efficient administrative tasks, virtual reality and simulations, and intelligent content creation (Chen et al., 2020). According to Chen et al. (2022), AI in education has the potential to revolutionize the learning process, making it more engaging, personalized, and effective. By leveraging AI technologies, educators can create a dynamic and adaptive learning environment that caters to the unique needs of each student, ultimately enhancing their educational outcomes.

2.2. ChatGPT

ChatGPT is a computer application cooperating with users using natural language based on a generative language model launched by OpenAI (Eysenbach, 2023). There are several roles of ChatGPT in educational settings, such as information or knowledge providers (Eysenbach, 2023). It is an AI tool that assists in writing, learning, performing assessments, creative writing, language translating, personal assistant tutoring or providing educational resources, as well as being a content generator, problem solver and entertainment provider (Fauzi et al., 2023; Khan et al., 2023; Strzelecki, 2023). Scholars emphasize that when users interact with the ChatGPT platform by posing questions or introducing new topics, ChatGPT responds with generative language sentences based on a knowledge base (Hwang & Chen, 2023). Investigators have specifically noted that this interactive mode using generative language greatly enhances ChatGPT's acceptance among the general public (Kung et al., 2023). Moreover, Wardat et al. (2023) further identified that utilizing ChatGPT can effectively enhance learners' problem-solving and critical thinking skills.

Recently, investigators have applied ChatGPT to several areas including science education (Cooper, 2023), an L2 writing practicum (Yan, 2023), medical education (Friederichs et al., 2023), early childhood education (Luo et al., 2023), health and physical education (Killian et al., 2023), and revolutionizing patient care and education domains (Ahmed, 2023). For example, Ahmed (2023) indicated that the utilization of ChatGPT in nurse education courses can offer simulated scenarios for virtual training, and simulated patient communication to nursing learners. This virtual experience has the potential to enhance learners' practical abilities and self-confidence, while providing them with greater learning opportunities in terms of diagnosis, guidance, and assessment. As a result, the learners' learning efficacy is improved. Yan (2020) implemented ChatGPT in an L2 writing class and discovered its effectiveness in enhancing the learners' writing outcomes. It is foreseeable that the progress of computer networks, mobile, and AI technologies could continue to promote the adoption of ChatGPT in diverse fields, as suggested by Hwang and Chen (2023).

2.3. The current study

Effective teaching and learning revolve around skillful questioning within the classroom. Student questioning is regarded as a crucial self-management strategy that yields multiple benefits in science education (Webb, 2005). These inquiries not only play a vital role in knowledge acquisition, discussions, self-evaluation, and fostering learning engagement, but also lead to tangible improvements in academic performance. For instance, the implementation of questioning strategies during the reading process was shown to significantly enhance reading

performance (Astrid et al., 2019). Xia (2020) pointed out that questioning strategies can also bolster second language learners' comprehension of text details and main ideas. Furthermore, Vacek and Liesveld (2020) implemented a Question strategy in nursing education. Throughout the teaching process, teachers guided learners to ask questions, aiming to foster their in-depth thinking and comprehension of concepts. The researchers observed that the application of this teaching method had a positive impact on nursing learners' learning and conceptual understanding. Moreover, it led to an improvement in their learning efficiency and satisfaction, while also enhancing their ability to apply acquired knowledge in actual nursing practice in the future.

Nevertheless, in a traditional classroom setting, student-initiated questions are relatively infrequent. Scholars have stated that teachers face the pressure of keeping up with the curriculum, which may restrict their ability to address every student's question within a single class session (Hsu et al., 2023; Kohnke, 2022). Consequently, this study delved into the utilization of ChatGPT, a generative language model, to optimize the communication pathway with learners, assisting them in formulating questions and accomplishing learning tasks. Through this approach, we aim to enhance the promotion of effective teaching and learning.

2.4. Critical thinking, problem-solving learning, and enjoyment

Problem-solving ability and critical thinking are essential core competencies that 21st-century learners need to possess (Baird & Parayitam, 2019; Song et al., 2022). Critical thinking involves learners objectively and systematically analyzing, evaluating, and synthesizing information, ideas, and arguments to make informed decisions and form sound judgments (Akbar, 2023). It encourages logical thinking, the evaluation of evidence, and drawing logical conclusions, enabling learners to solve problems and exercise good judgment in various situations. Developing critical thinking skills empowers individuals to face future challenges and complexities with intellectual rigor and insight.

Scholars propose that learners should possess "problem-solving ability," which entails acquiring knowledge, skills, and strategies to effectively identify, analyze, and resolve challenges and issues in diverse contexts (Gordon et al., 2021). This competency has significant value across different disciplines, and plays a crucial role in personal and professional development (Ábrahám et al., 2023). Thus, cultivating problem-solving skills is a vital task for today's educators.

Moreover, learning enjoyment refers to an emotional orientation that originates from the happiness and contentment learners experience during their educational endeavors (Jin & Zhang, 2021). By enhancing learners' learning enjoyment, they may develop a heightened interest in learning goals, leading to sustained learning and improved learning experiences (Hsu et al., 2023). This, in turn, enhances their critical thinking and problem-solving abilities.

It can be observed that education has become more student-centered and personalized, leading to enhanced learning outcomes for learners. Consequently, there is a growing necessity to consider individual differences during class activities and when integrating ChatGPT into educational practices (Hwang & Chen, 2023). ChatGPT has proven its effectiveness in assisting with complex pathology problems, such as explaining disease pathophysiology and providing diagnostic recommendations (Sinha et al., 2023). Educational researchers are not only involved in new pedagogical issues and methods, but have also embraced technology to facilitate efficient learning for learners in professional training, overcoming the limitations of location and time through cross-disciplinary cooperation (Aitchison et al., 2020). Vacek and Liesveld (2020) employed questioning strategies to support learners in comprehending nursing education concepts. In line with this, the present research applied ChatGPT's questioning strategies to enhance the learning efficacy of university learners enrolled in a health education design course. Learners interacted with ChatGPT through questioning strategies, with ChatGPT acting as the teacher to answer their queries, aiming to increase their learning enjoyment.

As a result, the adoption of ChatGPT technologies has gradually reshaped the role of teachers in educational environments. With the help of ChatGPT, instructors can focus more on guiding learners in thinking, practicing, and applying knowledge based on individual learners' needs, thereby improving the quality of teaching.

3. Method

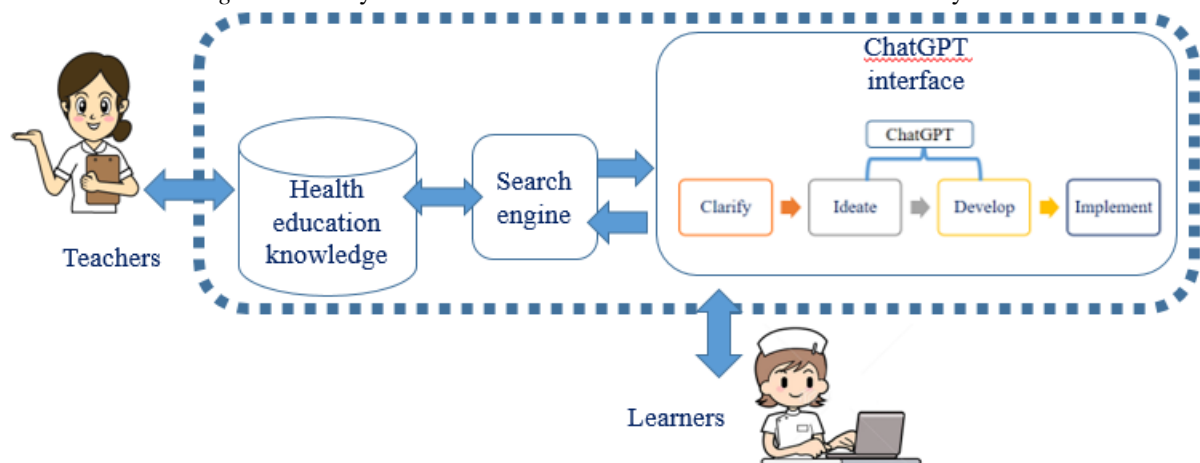
3.1. Development of the CIDI model-based ChatGPT

The study utilized Alex Osborn's creative problem-solving model, known as CIDI (Clarify, Ideate, Develop, Implement), to guide the problem-solving process (Osborn, 1953; Zhbanova, 2013). This CIDI method and process essentially involve four steps: (1) Clarify: In this step, learners need to identify and clarify the nature and scope of the problem. For example, learners must learn to define the learning task problem, determine learning objectives and goals, and understand the challenges and limitations in the problem-solving procedure. The purpose of this stage is to ensure that learners have a consistent understanding of the problem and lay the foundation for the subsequent ideation process. (2) Ideate: In the CIDI method, ideate is the most important and creative stage. Learners are encouraged to brainstorm and freely express ideas during this stage. Learners can provide more options for the subsequent selection of problem-solving methods, and propose diverse and rich solutions to the learning task. (3) Develop: Following the Ideate stage, learners will evaluate and conduct in-depth research on the various ideas or solutions generated. They can identify more promising ideas for solving the task and consider the feasibility and effectiveness of implementation, developing them into concrete and feasible solutions. (4) Implement: Learners can involve the actual implementation of the solutions developed through CIDI. It includes conducting experiments, testing, and making adjustments based on practical implementation.

The CIDI method and process is a systematic, practical problem-solving framework that helps learners be more organized and creative in problem solving. The approach has broad applications in business, innovation, education and other fields, helping people face challenges more effectively and find innovative solutions (Puccio et al., 2005).

The CIDI model-based ChatGPT system utilizes questioning strategies in knowledge inquiry to make decisions or provide assistance. The expertise of ChatGPT is derived from domain knowledge and non-domain-specific information, enabling it to respond to inquiries of varying depths. This research integrates ChatGPT's artificial intelligence capabilities as both an information and knowledge provider, allowing learners to interact with the system through questioning strategies. The generative language of ChatGPT serves as the knowledge repository, as depicted in Figure 1. During the interactive conversation between learners and the ChatGPT system, the requests and data from learners are interpreted by ChatGPT and related materials are retrieved from the repository. Subsequently, ChatGPT summarizes and formulates responses based on the retrieved information to provide answers to the learners.

Figure 1. The system architecture of the CIDI model-based ChatGPT system



In this instructional task example, learners are assigned to design a health education lesson plan in the form of a dietary education sheet for pregnant women within the first three months of pregnancy. This particular health education design is facilitated through the CIDI model-based ChatGPT system, offering interactive learning opportunities. Through the clarify phase, learners are required to ascertain and clarify the nature and scope of the dietary education task. This includes accurately defining the dietary issues associated with pregnancy, defining the determination and goals of the inquiry, and determining the tasks and constraints involved. The purpose of this clarify phase is to confirm that learners have a consistent understanding of the tasks, laying the groundwork for the subsequent process of creating the lesson plan. The instructional screen guides learners in how to utilize

the ChatGPT system effectively, as depicted in Figure 2. It delivers step-by-step instructions to support learners' understanding and mastery of the functionalities of the ChatGPT interface. Through interactive demonstrations, learners can learn how to input questions, analyze responses, and make use of the various available features. The activities also offer examples and practical exercises to enhance learners' proficiency in using ChatGPT as a powerful tool for knowledge inquiry and problem solving. By the end of the activities, learners will be equipped with the capability and confidence to leverage the ChatGPT system to its full potential.

Figure 2. Instructing learners on the ChatGPT system and method



Figure 3. Example of information retrieved and presented by ChatGPT

Please make a dietary education sheet for pregnant women within the first three months of pregnancy

please make a dietary education sheet for pregnant women within the first three months of pregnancy

Congratulations on your pregnancy! Here's a dietary education sheet for pregnant women within the first three months (first trimester) of pregnancy. It's important to focus on balanced and nutritious meals during this crucial time. Remember to consult with your healthcare provider for personalized advice and any specific dietary requirements.

Dietary Education for Pregnant Women - First Trimester (Weeks 1-12)

1. Key Nutrients:
During the first trimester, your body needs essential nutrients to support the growth and development of your baby. Focus on the following nutrients:

- **Folic Acid:** Crucial for the development of your baby's brain and spinal cord. Include folate-rich foods like leafy greens, fortified cereals, beans, and citrus fruits.
- **Iron:** Important for the formation of red blood cells in both you and your baby. Consume iron-rich foods like lean meats, beans, fortified cereals, and spinach.
- **Calcium:** Vital for your baby's bone development. Get calcium from dairy products (milk, yogurt), fortified plant-based milk, and leafy greens.
- **Omega-3 Fatty Acids:** Support your baby's brain and eye development. Eat fatty fish (low in mercury) like salmon, chia seeds, flaxseeds, and walnuts.
- **Protein:** Essential for cell growth and repair. Include lean meats, poultry, fish, eggs, legumes, and nuts.
- **Vitamin D:** Aids in calcium absorption and supports bone health. Spend time outdoors in sunlight and consume vitamin D-fortified foods or supplements if advised by your doctor.

2. Stay Hydrated:
Drink plenty of water throughout the day. Staying hydrated helps in maintaining amniotic fluid levels and supports the overall functions of your body.

3. Meal Planning:

- Aim for three balanced meals per day.
- Include a variety of fruits, vegetables, whole grains, lean proteins, and healthy fats in your diet.

Free Research Preview. ChatGPT may produce inaccurate information about people, places, or facts. [ChatGPT July 20 Version](#)

During the ideate phase of the instructional activity, teachers encourage learners to freely express their thoughts and opinions about their learning process. Learners can engage in interactive conversations with ChatGPT, exploring diverse solutions to clinical scenarios and collecting multiple options for making decisions in solving learning tasks. Through interactions with the ChatGPT system, learners have the opportunity to learn professional terminology and exercise critical judgment, fostering greater interactivity in the learning process. Moreover, they can practice repeatedly to become familiar with the questioning and response process facilitated by ChatGPT. Leveraging the knowledge-based ChatGPT system, learners are stimulated to complete learning tasks relevant to their chosen topics and address a series of questions. If learners make correct decisions or selections within the specified timeframe, their records are updated, as depicted in Figure 3.

Figure 4 depicts the learning scenario of the knowledge-based ChatGPT system undergoing training within a computer environment. One of the tasks involves determining the type of diet to respond to the instructional prompts. Learners can interact with ChatGPT to seek evidence supporting their instructional design tasks. During this stage of development, learners will evaluate and delve deeper into various ideas generated from the previous phase of ideation. They can explore ideas that best address the instructional task, and consider the feasibility and effectiveness of implementation based on the instructional objectives. Moreover, learners can use questioning strategies iteratively to familiarize themselves with knowledge related to pregnancy diets and transform it into a concrete and feasible instructional plan. Additionally, learners can further inquire and request, “Make a dietary education sheet for pregnant women with diabetes within the first three months of pregnancy,” to obtain different information, as illustrated in Figure 4.

Figure 4. Learners interact with ChatGPT during the learning process

Please make a dietary education sheet for pregnant women via diabetes within the first three months of pregnancy

The screenshot displays a ChatGPT response to the prompt: "please make a dietary education sheet for pregnant women via diabetes within the first three months of pregnancy". The response includes a congratulatory message and a detailed dietary education sheet titled "Dietary Education for Pregnant Women with Diabetes - First Trimester (Weeks 1-12)". The sheet is organized into five numbered sections, each with specific advice:

- 1. Balanced Meals:**
 - Aim for three balanced meals and two to three small, healthy snacks each day.
 - Include a variety of nutrient-dense foods, such as fruits, vegetables, whole grains, lean proteins, and healthy fats.
- 2. Carbohydrate Management:**
 - Monitor your carbohydrate intake and spread it throughout the day to help control blood sugar levels.
 - Choose complex carbohydrates like whole grains, legumes, and non-starchy vegetables over refined carbohydrates and sugary foods.
- 3. Glycemic Control:**
 - Focus on maintaining stable blood sugar levels.
 - Avoid large spikes in blood sugar by avoiding high glycemic index foods and sugary snacks.
- 4. Portion Sizes:**
 - Be mindful of portion sizes to prevent overeating and to better manage blood sugar levels.
- 5. Fiber-Rich Foods:**

On the left side of the image, five green boxes with blue borders are connected to these sections by lines:

- Balanced Meals** connects to **1. Balanced Meals:**
- Carbohydrate Management** connects to **2. Carbohydrate Management:**
- Glycemic Control** connects to **3. Glycemic Control:**
- Portion Sizes** connects to **4. Portion Sizes:**
- Fiber-Rich Foods** connects to **5. Fiber-Rich Foods:**

At the bottom of the ChatGPT interface, there is a "Send a message" input field and buttons for "Regenerate response" and "Screenshot". A footer note states: "Free Research Preview. ChatGPT may produce inaccurate information about people, places, or facts. ChatGPT July 20 Version".

In the final implementation phase, the developed dietary education sheet solution is put into practice. It is released to the robot for conducting health education testing, adjustments, and ultimately, presenting and sharing the instructional plan, as illustrated in Figure 5.

Figure 5. Learners implement and share the tasks in the activities via an educational robot



3.2. Experimental design

3.2.1. Participants

The purpose of this study was to engage learners in a nursing health education design course and to train them in the effectiveness of generating health education content using the CIDI model-based ChatGPT system. Nursing health education is a mandatory course in nursing schools and clinical internships, and it constitutes an essential part of nursing professional development. To evaluate the effectiveness of the proposed method, this research comprised a quasi-experiment. Fifty nursing learners, with an average age of 21, participated in the experiment. Among them, 25 learners in the experimental group learned with the generative AI system, while the remaining 25 learners in the control group were taught using the traditional lecture-based approach. To compare the critical thinking, problem solving, and enjoyment levels of the two groups, pre- and posttest questionnaires were administered.

3.2.2. Measuring instruments

This study's critical thinking scale was adapted from Lin et al.'s (2019) modification of the critical thinking disposition questionnaire developed by Chai et al. (2015). The scale assesses learners' awareness of their learning processes, such as decision making, task analysis, and evaluation. It consists of six items, one of which is: "During the learning process, I reflect on the correctness of what I have learned." The Cronbach's α value for this scale is .83.

The problem-solving scale used in this research originated from Hwang and Chen (2017). It comprises five items, including statements like "I often pause to check my level of understanding" and "I ask myself how well I have achieved the objectives after completing a task." Employing a 5-point Likert scale, the Cronbach's α value for this scale was .78.

The enjoyment scale utilized in this study was developed by Dixon et al. (2015). It consists of 19 items, such as "I seek ways to make this course enjoyable for myself" and "I genuinely want to learn the materials." This measure also employs a 5-point Likert scale, with a Cronbach's α value of .86.

All of the above scales utilize a 5-point Likert-style scale with response options ranging from *Strongly Agree* (5 points), *Agree* (4 points), *Neutral* (3 points), *Disagree* (2 points), to *Strongly Disagree* (1 point). Higher scores indicate better abilities, while lower scores reflect lower abilities.

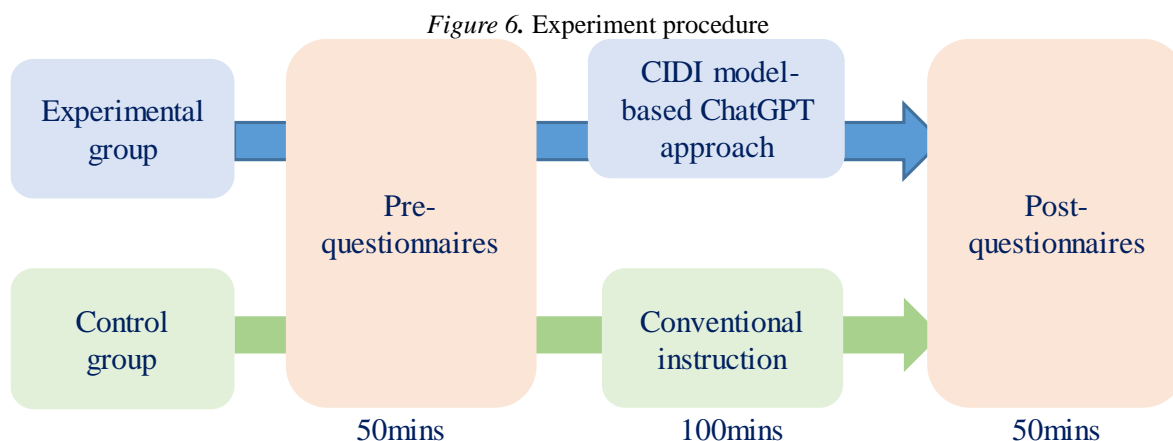
3.2.3. Experimental process

The experimental procedure is illustrated in Figure 6. Before engaging in the learning activities based on the CIDI model-based ChatGPT, the learners took a pretest to assess their foundational knowledge in nursing health education. They also filled out questionnaires related to critical thinking, problem solving, and enjoyment. During the learning activities, each group participated for a total of 4 hours.

The learners in the experimental group were guided to log into ChatGPT to practice and complete the tasks provided by the teacher. Each student interacted with ChatGPT individually to complete the self-study tasks in four time periods. There was a 10-minute break between each 50-min time period. Learners were allowed to engage in text-based interactions and conversations with ChatGPT. On the contrary, those in the control group received conventional teaching, wherein the teachers used relevant PowerPoint materials, images, and videos to illustrate the teaching content of the health education lesson plan.

It is worth noting that both groups were assigned to design a health education lesson plan in the form of a dietary education sheet for pregnant women within the first three months of pregnancy, focusing on identical learning content. The only difference between the two groups was the use of the CIDI model-based ChatGPT in the experimental group and the conventional internet search method in the control group. Both groups performed their tasks at different times. After the learning activities, the learners in both groups were assisted in completing posttests and post-questionnaires related to critical thinking, problem solving, and enjoyment.

During the practice and discussion stage, learners had the opportunity to inquire about health education project design and engage in discussions with their teachers or fellow classmates. They were guided to apply the knowledge they had acquired to address health education project cases presented by the teacher. Moreover, they were encouraged to exchange ideas and deliberate on their case decisions and dietary education recommendations, with a special focus on the initial three months of pregnancy, with their peers.



4. Experimental results

The IBM Statistical Toolset and Service Offerings, edition 22 (SPSS v.22), was employed to evaluate the outcomes of the experiment and to examine the validity and reliability of the study's instrument. To assess critical thinking and decision-making, along with the learning enjoyment of learners' learning through varying methods (for instance, the CIDI paradigm-driven ChatGPT versus traditional teaching methods), we utilized ANCOVA (Analysis of Covariance). The outcomes from the Shapiro-Wilk examination for distinct measures range from 0.88 to 0.90 ($p > .05$). This suggests that the datasets for each measurement align with a normal distribution.

4.1. Critical thinking

In this study, the critical thinking pretest served as the covariate, and the critical thinking posttest was the dependent variable. The homogeneity assumption was validated through Levene's test, showing $F(1, 48) = 1.05$ ($p > .05$). Moreover, the assumption of regression homogeneity was not violated, as evidenced by $F(1, 46) = 10.19$ ($p > .05$). ANCOVA was utilized for post-hoc analysis to compare the two groups. The ANCOVA results in Table 1 revealed that learners using the CIDI model-based ChatGPT learning method (Mean = 4.73; $SD = 0.44$) had significantly higher critical thinking than those using the conventional learning method (Mean = 3.88; $SD = 0.51$), $F(1, 47) = 33.22$ ($p < .001$).

The adjusted values for the experimental group and control group were 4.71 and 3.89, respectively, indicating that the CIDI model-based ChatGPT learning approach significantly improved learners' critical thinking compared to the conventional learning method. Moreover, the correlation coefficient ($\eta^2 = 0.414$) exceeded

0.138, suggesting that the CIDI model-based ChatGPT learning method had a substantial positive influence on learners' critical thinking. In other words, the CIDI model-based ChatGPT learning method effectively improved learners' critical thinking. The experimental results of this study confirmed that the CIDI model-based ChatGPT learning method could effectively enhance learners' critical thinking.

Table 1. Results of ANCOVA on learners' critical thinking

Group	<i>N</i>	Mean	<i>SD</i>	Adjusted Mean	Std. error	<i>F</i>	η^2
Experimental group	25	4.73	0.44	4.71	0.09	33.22***	.414
Control group	25	3.88	0.51	3.89	0.09		

Note. *** $p < .001$.

4.2. Problem solving

This study used the problem-solving pretest as the covariate and the problem-solving posttest as the dependent variable. .05). Moreover, the assumption of regression homogeneity was not violated, as evidenced by $F(1, 48) = 0.01$ ($p > .05$). For post-hoc analysis between the two groups, ANCOVA was utilized. The ANCOVA results in Table 2 revealed that learners using the CIDI model-based ChatGPT learning method (Mean = 4.53; $SD = 0.71$) had significantly better problem solving compared to those using the conventional learning method (Mean = 3.75; $SD = 0.58$), $F(1, 47) = 24.53$ ($p < .001$). The adjusted means for the experimental and control groups were 4.63 and 3.65, specifying that the CIDI model-based ChatGPT learning method better enhanced learners' problem solving when compared to the conventional learning method. Moreover, the correlation coefficient ($\eta^2 = 0.343$) exceeded 0.138, suggesting that the CIDI model-based ChatGPT learning method had a substantial positive influence on learners' problem solving. In other words, the CIDI model-based ChatGPT learning method effectively improved learners' problem-solving ability. The experimental results of this study confirmed that the CIDI model-based ChatGPT learning method could effectively enhance learners' problem-solving ability.

Table 2. ANCOVA of problem solving comparing the experimental and control groups

Group	<i>N</i>	Mean	<i>SD</i>	Adjusted Mean	Std. error	<i>F</i>	η^2
Experimental group	25	4.53	0.71	4.63	0.13	24.53***	.343
Control group	25	3.75	0.58	3.65	0.13		

Note. *** $p < .001$.

4.3. Learning enjoyment

The learning enjoyment pretest was employed as the covariate, and the learning enjoyment posttest was the dependent variable. The homogeneity assumption was proved using Levene's test, $F(1, 48) = 1.00$ ($p > .05$). Additionally, the assumption of regression homogeneity was not violated, with $F(1, 46) = 10.89$ ($p > .05$). Accordingly, ANCOVA was employed. Table 3 revealed that learners using the CIDI model-based ChatGPT learning method (Mean = 4.69; $SD = 0.46$) had significantly higher learning enjoyment compared to those using the conventional learning method (Mean = 3.61; $SD = 0.68$), $F(1, 47) = 15.46$ ($p < .001$). The adjusted means for the experimental and control groups were 4.49 and 3.81, showing the effectiveness of using the CIDI model-based ChatGPT learning method for enhancing learners' learning enjoyment. Moreover, the correlation coefficient ($\eta^2 = 0.248$) exceeded 0.138, suggesting that the CIDI model-based ChatGPT learning method had a substantial positive influence on learners' learning enjoyment. In other words, the CIDI model-based ChatGPT learning method effectively improved learners' learning enjoyment. The experimental results of this study confirmed that the CIDI model-based ChatGPT learning method could effectively enhance learners' learning enjoyment.

Table 3. Results of ANCOVA on learners' learning enjoyment

Group	<i>N</i>	Mean	<i>SD</i>	Adjusted Mean	Std. error	<i>F</i>	η^2
Experimental group	25	4.69	0.46	4.49	0.11	15.46***	.248
Control group	25	3.61	0.68	3.81	0.11		

Note. *** $p < .001$.

5. Discussion and conclusions

The study incorporated a CIDI model-based ChatGPT system into a health education design class, utilizing computers to facilitate learners' practice of nutrition knowledge for pregnant women during the learning activities. The study results specified that the CIDI model-based ChatGPT system effectively boosted learners' critical thinking, problem solving and learning enjoyment compared to conventional teaching. According to learning theories, to enhance our study, we planned to delve deeper into the interactions between learners and the ChatGPT system. We aimed to employ the Constructivist Theory, Cognitive Load Theory, and Flow Theory to better comprehend the observed improvements in a holistic manner. Previous studies have indicated that the constructivist learning theory correlates with enhanced critical thinking and problem-solving skills, suggesting that learners actively shape their knowledge. In designing future iterations of the ChatGPT system, which is based on the CIDI model, we aspired to create an environment where learners were actively engaged, posing questions, and reflecting on their insights. Such dynamic interactions underpin a profound understanding and knowledge application, thereby fostering critical thinking.

As for critical thinking, the experimental data revealed that the integration of the CIDI model-based ChatGPT system positively influenced learners' critical thinking. This outcome is consistent with previous studies that have investigated the use of chatbots in educational contexts. For instance, Chang et al. (2022) employed a chatbot in a nursing course, and found that the chatbot was able to guide learners to make judgments in physical examination, thereby strengthening their critical thinking skills. As a result, the learners achieved better learning performance compared to those who underwent conventional teaching methods. Past research has also indicated that using an interactive learning mode, which provides situational contexts and guidance, would facilitate learners' critical thinking (Adur, 2022; Kohnke, 2023).

Regarding learners' problem solving, it was found that the learners who utilized the CIDI model-based ChatGPT system demonstrated its advantages in the health education design course. The CIDI model-based ChatGPT system offered an interactive learning mode, enabling learners to acquire relevant knowledge based on their learning progress, thus providing personalized learning opportunities. This aligns with the findings of Setyosari et al. (2023), who emphasized that enhancing problem-solving skills depends on the learning design's ability to cater to individual student needs, leading to improved learning efficacy.

As for learners' learning enjoyment, the research showcased that participants favored using the CIDI model-based ChatGPT system during the learning process. The conventional teaching mode focuses more on delivering lectures with multimedia content; there are often limited opportunities for interaction between teachers and learners, as well as a lack of immediate feedback to the learners. One significant advantage of the CIDI model-based ChatGPT system is likely its capability to offer instant feedback, facilitating engagement and enabling learners to study efficiently according to their needs (Acquah & Katz, 2020). Hsu et al. (2023) also supported the idea of using computer systems to facilitate interactions to enhance learners' enjoyment.

The CIDI model-based ChatGPT system offers valuable assistance to users in making appropriate choices and conducting systematic studies focused on specific learning content. Simultaneously, the system provides practice materials suitable for different learning levels, tailoring them to learners' individual learning progress and helping them identify and address any misconceptions during the practice. As a result, the CIDI model-based ChatGPT system offers personalized practice and guidance, leading to improved learning efficiency and effectiveness. In this learning process, learners take an active role in knowledge construction while the CIDI model-based ChatGPT system serves as an assistant and learning facilitator.

The findings of this study further support Hwang and Chen's (2023) suggestion that ChatGPT systems can fulfill various roles for educational purposes. While several ChatGPT in education studies have focused on analyzing and predicting learners' perceptions of using ChatGPT, the present study demonstrates that ChatGPT systems can benefit learners by acting as a tutor. Consequently, teachers could have more time to address the challenges learners have encountered; moreover, personalized learning supports can be provided based on individual learners' requirements. If learners download the CIDI model-based ChatGPT system onto their tablets or smartphones, it transforms into a Smart Learning Partner. Consequently, learners can adapt their learning approach, accessing teaching materials that suit their preferences and repeatedly reviewing unfamiliar content. This sense of having a learning partner with shared learning goals enhances their cognitive development and creates a more enriching learning experience.

Despite obtaining the expected results, this study has limitations attributed to its research design and the instructional context. For instance, the research focus was solely on nursing learners, and it is suggested that

future studies encompass learners from various disciplinary backgrounds. Furthermore, the inability to track learners' learning process using the CIDI model-based ChatGPT system limited the understanding of their learning experiences and challenges. Additionally, the relatively small sample size poses a limitation to this study. Based on the limitations and findings of this research, the following recommendations are proposed for future studies on the application of ChatGPT in education:

- Investigate the relationship between learning methods based on ChatGPT systems and individual characteristics, that is, learning achievement, cognitive load, metacognition, or self-efficacy, and their learning performance and perception. Different learners with diverse individual traits and learning statuses may be impacted differently by the integration of ChatGPT technology.
- Apart from nursing learners, school teachers, patients, patients' families, caregivers, and healthcare professionals also require continuous learning and updates on health-related knowledge. Therefore, studying the benefits of the CIDI model-based ChatGPT system for these learners is equally essential.
- In traditional teaching environments, teachers often face challenges in understanding learners' learning situations and difficulties that may require additional guidance. In the future, using ChatGPT applications to analyze the learning process of struggling learners could allow teachers to gain insights into their learning status and provide personalized support. Moreover, teachers can use this information to improve learning content or design ChatGPT-based instructional activities. Integrating classroom management into educational applications based on the CIDI model-based ChatGPT system should also be considered.
- While recent research has primarily focused on language education applications based on ChatGPT, it is suggested to undertake interdisciplinary research to delve deeper into the educational applications of the CIDI model-based ChatGPT system. Additionally, future studies could explore the incorporation of various learning strategies, that is, game-based learning, peer assessment, and self-directed learning, in the design of CIDI model-based ChatGPT-based learning.
- Exploring the long-term impact of the approach on learners' attitude, learning behavior, and learning performance is crucial. Understanding the benefits of using the CIDI model-based ChatGPT system, which relates to active and self-directed learning, can provide personalized learning opportunities. Given the potential limitations of ChatGPT, it is vital for readers and future researchers who intend to use ChatGPT in medical education to ensure that users discern accurate medical knowledge.

The main contribution of this study lies in proposing a learning approach based on the CIDI model-based ChatGPT system and demonstrating its effectiveness across multiple dimensions. The research findings can serve as a reference for researchers preparing to implement ChatGPT in education and school teachers planning to enhance learners' learning outcomes through the utilization of ChatGPT technology.

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