Case-based Professional Learning Course for Fostering Preservice Science Teachers' Technological Pedagogical and Content Knowledge of Inquiry with Mobile Game

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Abstract: Technological Pedagogical and Content Knowledge (TPACK) is a framework for teacher professional development. In current teacher education research, pre-service teachers are targeted to improve their teaching competencies based on implementing TPACK as an integrative framework of instructional interventions. This study purposed to investigate an effect of a TPACK-oriented mobile game learning in science (MGLS) module based on pre-service science teachers' subject-specific teaching knowledge development. The researchers implemented the MGLS to 31 sophomore pre-service science teachers at a former university's public teacher in the northeastern region of Thailand. They were assigned to attend the MGLS within three weeks. They have been measured individual TPACK using a multiple-choice test before and after participating with the MGLS module. The findings illustrated that there was a significant difference between their TPACK scores of pre- and post-test. This result revealed that the MGLS could improve pre-service science teachers' TPACK. In addition, most pre-service science teachers in this study also intended to use the mobile game in nature of enhancement student learning with specific science content.

Keywords: TPACK, mobile game, pre-service science teacher

1. Introduction

Today's world demands more efficient learning models that allow students to play a more active role in their education. Technology is having an impact on how instruction is delivered and how information is found and share. Nowadays, technologies have changed the educational model and access to information. Mobile devices have become a complete set of applications that can be developed (Criollo-C et al., 2021). Recently, mobile technology in teaching and learning is a strategic topic for many organizations concerned with education (Ally & Prieto-Blázquez, 2014) that is considered an effective way to improve students' learning outcomes (El-Sofany, & El-Haggar, 2020). The teachers can provide new learning opportunities and enhance the teaching and learning process, such as context awareness and ubiquity, personalization and adaptiveness, communication, and collaboration among learners (Khaokhajorn et al., 2020). It can facilitate students' learning anytime, anywhere and carry out various activities such as listening, watching videos taking photos, and videos (Nikolopoulou & Kousloglou, 2019; Hwang et al., 2018). According to mobile phones are increasingly becoming part of the dairy of today's youth. Widespread usage of mobile phones is the primary motivating factor for researchers to look into their utility in formal and informal education (Iqual et al., 2017). Several learning improvement studies in science education can be achieved by utilizing mobile technology because mobile learning can solve that problem. It enables adjustment of the curriculum to meet students' learning time and life situations. It provides different solutions better than traditional educational methods (Elkhateeb, Shehab, & El-bakry, 2019). In the context of science education development, many researchers and educators efforted to transform science-specific abstraction, complexity, and invisible features into simplifications for better inquiry learning in science. The mobile game is an effective inquiry tool to promote students' learning comprehension and motivation. Mobile game-based inquiry learning can boost internal motivation that brings up the fun of learning to students and supports a better learning experience fitting their learning preferences. Moreover, the inquiry with the mobile game allows more interaction and freedom to enjoy through the course and at their own pace (Yadav & Oyelere, 2021). To use the mobile game effectively, teachers desire a specific kind of knowledge to appropriately implement games in their teaching: technological pedagogical and content knowledge (TPACK) (Hsu, Liang, & Su, 2015).

The TPACK framework builds on Shulman's (1986) pedagogical content knowledge framework (PCK) by including technological knowledge into the PCK framework. It is an essential part of the professional teaching knowledge and was first proposed by Mishra and Koehler (2006). TPACK provides a good framework for the knowledge system of pre-service teachers' training. New generation teachers in the 21st century should not only pay attention to the improvement of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), but to how to integrate different levels of knowledge to cultivate teachers and develop teacher education as well (Wang, Gu, & Liu, 2020). Santos and Castro (2021) suggested that TPACK theory brings the challenge of its implementation in the classroom. Not all teachers could effectively deliver the lesson with the integration of technology. As such, continuous professional training for both faculty of education and practice in school is very important. Therefore, preparing pre-service teachers for mobile technology is very important for high-quality teaching competencies in science (Smarkola, 2008). Thus, this study aimed to investigate mobile game learning in science modules based on the TPACK framework for pre-service science teachers' TPACK development.

2. Literature Review

2.1 Technological Pedagogical and Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) was proposed by Mishra and Koehler (2006) for understanding essential teacher knowledge in this recent. The TPCK framework was renamed for simple calling. It added, "and": technology, pedagogical, and content knowledge that is called "TPACK" (Thompson and Mishra, 2007). This framework extended from Shulman's (1986) construct of pedagogical content knowledge (PCK). TPACK explained to integrate content knowledge, pedagogical knowledge, and technological knowledge. The framework represents crucial teacher knowledge to conform technology into their teaching, particularly content knowledge (Srisawasdi, 2012). There were three overlapping circles of foundation knowledge such as the knowledge about the actual matter that called content knowledge (CK), the methods of teaching and learning knowledge which is called pedagogical knowledge (CK), and the knowledge about standard/ digital technologies and the skills needed to use specific technologies called technological knowledge (TK). These three foundation pieces of knowledge overlapped to occur four integrating pieces of knowledge consist of the knowledge about a definite teaching method that suitably matches the specific content called pedagogical content knowledge (PCK), the knowledge the standard technologies/ digital technologies that accordingly adopted to assist the teaching methods called technological pedagogical knowledge (TPK), the knowledge about technologies which transformed the actual subject matter easier and called technological content knowledge (TCK), and knowledge about the relationship among three areas such as content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) was forceful to merge for effective teaching called technological pedagogical and content knowledge (TPACK).

In more detail, seven knowledge-object components are represented in the TPACK framework (see Figure 1). Mishra and Koehler (2006) described as:

1) Content Knowledge (CK): The knowledge about the actual subject matter which teachers have to know.
2) Pedagogical Knowledge (PK): The knowledge about the teaching methods and processes such as lesson plan, classroom management, and student learning.
3) Technological Knowledge (TK): The knowledge about varied technologies from standard technologies, such as essential learning tools (a pencil and paper), to digital technologies, such as interactive whiteboards, internet, digital video, animation, and software programs.

4) Pedagogical Content Knowledge (PCK): The knowledge connects between the teaching methods and specific subject matters. Pedagogies have appropriately step to develop effective teaching in specific content.
5) Technological Content Knowledge (TCK): The knowledge about how technologies can transform specific content to simply.
6) Technological Pedagogical Knowledge (TPK): The knowledge about how to use matching technologies to support teaching.
7) Technological Pedagogical and Content Knowledge (TPCK): The essential knowledge for teachers about integrating technologies into their teaching in any specific content.

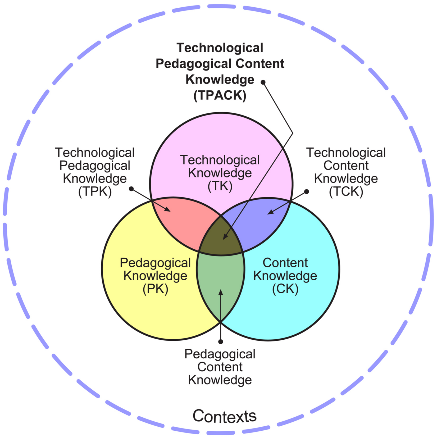


Figure 1. Technological Pedagogical and Content Knowledge (TPACK) http://tpack.org.

This framework helps teachers in activity-based strategies than expository or lecture methods that tag as a teacher-centered approach in learning.

2.2 Mobile Game-based Learning in Science Education

A popular activity among children is the use of mobile devices and apps. Nevertheless, the impact of mobile devices on learning and development is relatively underexplored. The use of mobile technologies places the student at the center of the teaching-learning process. Due to this, a teacher is the only mediator between content and knowledge. Mobile learning technology allows multiple learning models, thus managing to involve students in constructing their learning. The use of mobile devices would become a necessity in a modern educational system. The rapid growth of applications and mobile devices such as tablets and smartphones present many possibilities for the sharing and production of content in a format that explores new forms of learning (Criollo-C et al., 2021). Mobile game learning has become a good option in the learning model. Mobile game learning uses smartphones and tablets to run applications so learning content can be accessed using a smartphone or tablet. Mobile learning gives potentiality and practicability to transform education in the digital era. Furthermore, mobile games do not require many pages of books and can be incorporated into the handset to carry them easily. Learning is designed for use on mobile devices. Mobile games can be used on any mobile phone provided that the appropriate operating system base is installed. M-GBL media can be learned anywhere, anytime, by the students to obtain and explore the subject matter more effectively (Cahyana et al., 2017). Gamification improves science education teaching and boosts student motivation, engagement, and learning outcomes (Kalogiannakis et al., 2021).

3. Methods

3.1 Study Participants

The participants consisted of 31 pre-service science teachers (PSTs). They were sophomore, second-year students in a four-year bachelor’s degree of education in a public teacher former university located in the northeastern region of Thailand. There were 27 (87.1%) females and four (12.9%) males. Their average age was 19-20 years old. They enrolled in a contemporary learning management course delivered by the university, and they did not have experience using a mobile game for science teaching and learning before.

3.2 The Mobile Game Learning in Science (MGLS) Module

This study used a quasi-experimental research design which collected data pre- and post-intervention. It presented integrative technology into science teaching for using a mobile game in inquiry-based learning in Figure 2. The participants were introduced to the mobile game learning in science (MGLS) module for promoting their TPACK. The MGLS module consisted of 4 three-hour weekly lectures and practical work and was divided into three phases: showing the case (S), practice in team (P), and application of the case (A). It is briefly called "SPA," as shown in Table 1.

Table 1. *Details of MGLS Module for Pre-service Science Teacher Preparation based on TPACK*

Phase	Week	Topic	Learning strategy	Knowledge domain
S	1 (4 h)	Introduction to mobile game in science learning	Interactive lecture and demonstration	TK, TCK
P	2 (4 h)	Pedagogy of inquiry-based learning and hands-practical work with mobile game	Interactive lecture, demonstration, and hands-on practical work	TPK, TPACK
A	3 (4 h)	Designing mobile game learning activities in science	Hands-on practical work	TPACK

Figure 2. An illustration of the first phase, showing research case of mobile game in science learning.

For the S phase in the first week, the instructor (the first author) presented a research case focused on using a mobile game in biology class. In this case, researchers found out the difficulty point of circulatory system content. It is a complex and invisible phenomenon. The findings from many previous researchers found that digital games can enhance motivation to learn. Therefore, Lokayut and Srisawasdi (2014) designed and developed a digital game called "Red Blood Cell Simulator" for supporting secondary school students' learning on the blood circulatory system of the human body and enhancing learning motivation. This game can explain the structure of the human heart and how blood circulates in human body. They provided their students to learn through Student-associated Game-based Open Inquiry that was shortly called "SAGOI." Their findings illustrated that digital game-based inquiry learning enhanced students' motivation and fostered understanding (Lokayut and Srisawasdi, 2014). According to the research case, the instruction described and demonstrated how to apply digital games into inquiry learning in science, as shown in Figure 2.

In the P phase, the instructor provided a hands-on activity based on the research case in the previous phase. For this study, we developed to switch from version on the computer to a new version that can play on a smartphone, as shown in Figure 3.

Figure 3. An illustration of the second phase, practice in a team using mobile game-based inquiry learning.

In the A phase, PSTs were assigned to design mobile game-based inquiry learning by themselves. Individual PST appropriately chose a mobile game to design a science learning activity and your ideas in an online class. Figure 4 shown individual PST's presentation of mobile games for science learning.

Figure 4. An illustration of the third phase, pre-service science teachers' presentation of teaching idea with the support of the mobile game.

3.3 Data Collection and Analysis

This study examined the effects of using training intervention to foster pre-service science teachers' TPACK. Before and after this module, the participants were asked to measure TPACK comprehension. We used a ten-item close-ended question that covered seven components of TPACK. To confirm the normality of distribution of our data, the researchers performed the Shapiro- Wilk test, and the normality of distribution of data was accepted both pre-test ($W = 0.907; p > 0.000$) and post-test ($W = 0.963; p > 0.000$). The pre-service science teachers' scores on the scales of TPACK fit the assumptions of the normal distribution, and the researchers implemented paired t-test to examine the pre-service science teachers' TPACK changed after received intervention. Consequently, statistical analysis for quantitative data of TPACK scores from pre-test and post-test were analyzed with mean, standard deviations, and paired t-test to compare a significant difference. For assessing mobile game learning in science was categorized into four levels (Informed, Mixed, Naïve, and Unclear) adapted from Bartos and Lederman (2014)'s idea of teaching conception analysis. A respondent responded consistently across the entire questionnaire that was wholly congruent with the target response for a given aspect of TPACK; they were labeled as "*Informed.*" If, by contrast, a response is either only partially explicated and thus not consistent with the targeted response regarding TPACK, or if a contradiction in the response is evident, a score of "*Mixed*" is given. A contradictory response to accepting views of a specific aspect of TPACK under examination is scored as "*Naïve.*" Lastly, for incomprehensible, intelligible scores indicate no relation to the particular aspect, a categorization of "*Unclear*" is assigned (Lederman et al., 2014). All the statistical tests were used the IBM SPSS program, version 23.00, with a significant level of .05.

4. Results and Discussion

For exploring the effect of the MGLS module on pre-service science teachers' TPACK components, the result shows in Table 2.

Table 2. *Paired t-test Results of the Difference between the pre- and post-test TPACK Scores*

Test	N	Mean	Std. Deviation	t	*p*
Pretest	31	5.06	1.62	3.124	.004*
Posttest	31	6.19	1.36		

*$p < .05$

Pre-service science teachers' pre- and post-test TPACK scores are presented in Table 2. The results illustrated that there was a significant difference between the pretest (M = 5.06, SD = 1.62) and posttest (M = 6.19, SD = 1.36) scores. TPACK significantly improved after participating in the MGLS module (t = 3.124, $p < 0.05$).

Table 3. *Percentage of Preservice Science Teachers' Science Learning Activity Categorized as Holding unclear, naïve, mixed, informed view*

View	N	Percentage
Unclear	0	0.00
Naïve	0	0.00
Mixed	28	90.32
Informed	3	9.68

The pre-service science teachers' science learning activities were *Mixed* view (90.32%) and *informed* view (38.71%), shown in Table 3. The researchers categorized the type of using the mobile game to design science activity that identified two types: game-enhanced learning (61.29%) and Game-assisted learning (38.71%), the results are shown in Table 4.

Table 4. *Percentage of pre-service science teachers' mobile game science learning types*

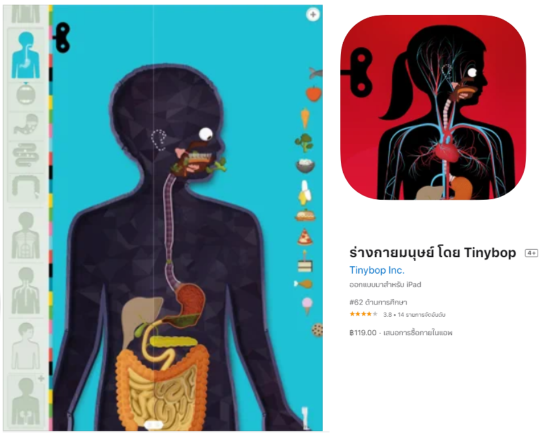
Type	N	Percentage
Game-assisted learning	12	38.71
Game-enhanced learning	19	61.29
Game-supported learning	0	0.00
Game-transformed learning	0	0.00

Table 5. shown examples of responses to design science learning activities by using the mobile game. The researchers chose from responses of pre-service science teachers who were labeled *informed* view and *Mixed* view.

Table 5. *Exemplary Science Learning Activities in informed and mixed Level*

Science learning activity	
Informed view	Mixed view

"I chose "cell puzzle" on the website http://planeta42.com to teach about the organelles in plant and animal cells. For playing, playera moved the mouse to place organelles on the cell image. I designed a learning activity that included open inquiry. There were three main steps: pre-inquiry, inquiry practice, and post-inquiry. First, the teacher provided an open-ended question and basic information. Second, the teacher described the rules of the game before. Students interacted with the game about reaching the goal on time- by following the rules and moving less than 21 times. Then-student volunteer students presented how to finish the game and answered the open-ended question. The teacher asked questions and discussed to summarize the structure of plant and animal cells.



I chose to use the application "human body by Tinybop," which you can search in the app store. I used this game to teach the human digestive system through 5Es, such as 1. Engagement: the teacher asked questions to check the students' prior knowledge and explained the organs and structure. 2. Exploration: The teacher divided students between playing games. 3. Explanation: a volunteer student introduces the game. The teacher discussed and summarized the organs and their function in the digestive system. 4. Elaboration: students were assigned to draw the human digestive system. 5. Evaluation: students share their feelings. Teacher evaluates learning behaviors.

In summary, the results of this study indicated MGLS that can foster pre-service science teachers' TPACK. The majority of their science learning activity was *Mixed* view, and they used the mobile game to enhance science learning. This finding related to Sancer-Tokmak et al. (2014) examined PSTs' perceptions of their TPACK development after creating digital stories based on science topics drawn from the national curriculum. The PSTs enrolled in Introduction to Computers II. Their technological knowledge, pedagogical knowledge, and content knowledge improved during the course. In addition, Lehtinen, Nieminen, & Viiri, (2016) investigated the effect of intervention regarding the use of simulations in science teaching on primary school pre-service science teachers' self-assessed TPACK. The results showed statistically significant differences between pre-service teachers' pre- and post-tests in content knowledge, pedagogical knowledge, and TPACK domains. Pondee, Premthaisong, & Srisawasdi (2017) implemented the framework for designing a module of the pedagogy of Mobile Laboratory Learning in Science (MLLS)for pre-service science teachers. They examined the efficacy of the MLLS for enhancing pre-service science teachers' TPACK. The results showed that the pre-service science teachers had improved their conceptions of TPACK to a higher level after interacting with the MLLS module. Kılıç, Aydemir, & Kazanç (2019) investigated the effect of the TPACK based blended learning environment on PSTs' TPACK and classroom practices involving the topics of day-night and season. The findings of this study showed a significant difference in favor of the post-test results between the pre-test and post-test about PSTs' TPACK and classroom practices involving the topics of day-night and seasons. The results indicated that a TPACK-based blended learning environment made an essential contribution to developing PSTs' TPACK and classroom practices. Pondee, Panjaburee, & Srisawasdi (2021) designed and created education courses with mobile game technology in two cohorts. The results showed pre-service science teachers' TPACK improvement from implementing the usual separated and integrated case-based TPACK support module.

5. Conclusion

The present study explores the effect of MGLS intervention on pre-service science teachers' TPACK improvement. The results indicate a significant difference between their TPACK scores at the pre- and post-tests, and this revealed that the case-based approach in MGLS improved their TPACK of mobile game in the school science setting. Therefore, this implies that the case-based MGLS could effectively develop their essential knowledge of mobile game learning in science. However, more teacher education research needs to be conducted to maximize pre-service science teachers' TPACK by redesigning the pedagogic module of mobile game-based inquiry learning in science.

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