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Implementing an Inquiry Learning with Mobile-supported Mathematical Board Game to Promote Primary Students' Attitude toward Mathematics Learning

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Abstract: One of the teaching approaches most used by educators is the inquiry-based learning, and with the development of technology, students have access to more games. Therefore, many researchers have integrated investigative learning methods with mobile-supported board games. The purpose of this research is to investigate students' conceptual understanding and their attitude toward mathematics learning using inquiry-based learning methods and mobile-supported board games. In this study, the participants were primary school students in the northeastern region of Thailand. The finding demonstrated that students have better conceptual understanding after using an inquiry learning with mobile-supported mathematical board game. Moreover, students had a positive attitude toward mathematics learning. Specifically, it allowed students to gain confidence and motivated them to study mathematics. Consequently, this study revealed that an inquiry-based learning combined with mobile-supported board game has the potential to foster positive attitudes towards mathematics learning with technology and may develop into other content in future primary mathematics learning.

Keywords: Board game, Inquiry-based Learning, Mathematics, Attitude

1. Introduction

Digital technology is now widely embraced in education, especially in subjects such as mathematics, aiming to boost students' understanding and enthusiasm. Educators are increasingly turning to digital technologies to create engaging learning environments that blend entertainment with education. For example, researchers have designed digital board games to enhance students' learning (Premthaisong & Srisawasdi, 2020; Nukprach, Chaipidech & Srisawasdi, 2023), and Chang and Panjaburee's research in 2022 demonstrated that Virtual Reality technology positively impacts learners' achievements, problem-solving abilities, and engagement. In the area of mathematics in primary school, the difficulty of effectively transferring new knowledge due to students accepted unfavorable views towards the subject is significant (Ardelenau, 2019). The study shown the potential for improved learning outcomes and improved attitudes when modern digital technology-infused learning environments are used to encourage investigative problem-solving (Ardelenau, 2019). One of the approaches that many researchers adapt for teaching in the classroom, is inquiry-based learning. For example, the complexity of classifying quadrilaterals, as demonstrated by Japanese sixth graders' tendency to perceive rhombuses differently from parallelograms, encourage educators to employ a variety of teaching approaches, such as inquiry-based learning (Okazaki & Fujita, 2007). Moreover, an inquiry-based learning fosters problem-solving skills and cognitive engagement by encouraging systematic knowledge exploration (Kohen, Schwartz-Aviaia, & Peleg, 2023). This strategy holds promise for facilitating students' solution discovery and fostering positive attitudes while confronting difficult mathematical problems, thereby contributing to a deeper appreciation for mathematics.

From the benefit of digital technology and the inquiry-based learning approach, many instructors utilize inquiry-based learning integrated with digital technology, such as Srisawasdi and Punjaburee (2019), which used a game-transformed inquiry-based learning approach to teach high school students about chemistry. In the area of mathematics, as reported by Lin and Cheng (2022), the use of digital technology and the inquiry-based learning approach in mathematics education has been found to have a positive impact on students' motivation and accomplishment of goals. Consequently, this study incorporates mobile-supported board game into an inquiry-based learning can be considered a pedagogical approach for technology-enhanced mathematics education, to promote students' understanding of concepts and positive attitudes toward mathematics learning.

2. Literature Review

2.1 Mobile-supported board game

Due to the benefits of game-based learning and technology, many educational researchers are interested in how to use smart phones to support students' learning. Numerous research studies have demonstrated that the integration of technology-supported game-based learning has the potential to enhance student motivation and foster improved conceptual comprehension across various academic disciplines, including mathematics and science. For example, Chao et al. (2018) posited that mobile-supported game-based learning in mathematics, can enhanced students learning. In addition, according to Lin and Cheng (2022), the utilization of technology-enhanced board games has been identified as a valuable approach for enhancing students' motivation and improving their academic performance in the context of primary mathematics. Moreover, according to the findings of Yeo and Campbell (2022), most a primary mathematics teacher in the USA agreed that the utilization of games that were supported by technology are an effective tool for teaching mathematics.

2.2 Inquiry-based Learning in Mathematics

Inquiry-based learning (IBL) is a learning approach that emphasizes developing problem-solving abilities, by training learners to investigate knowledge by questioning students to use their thinking process and finding logical conclusions, or to self-correct solutions. Many researchers employed Inquiry-based Learning to integrate with various technologies. According to Kohen et al. (2022), the utilization of Inquiry-based learning combined with technology has been shown to be a successful approach in the instruction of mathematics as well as this finding, it corresponds to Pedersen and Haavold (2023), who showed that IBL has potential in fostering a positive attitude and attraction towards the mathematics learning for students in the age-range 11-16. In addition, Radmehr et al. (2023) presented the potential of inquiry-based learning as a more effective pedagogical approach to instructing undergraduate students. It was found to enhance students' conceptual understanding, particularly in complicated mathematical topics. Furthermore, the implementation of Inquiry-Based Learning in Mathematics classes promoted a positive learning environment and attitudes towards mathematics (Aldridge & Robinson, 2022).

3. Research Methodology

3.1 Research Design

The research design was one group pre-test and post-test design. The participants were selected by using a purposive sample, in this case fifth-grade students. The data collection instruments consist of an attitude questionnaire and a quadrilateral conceptual test.

3.2 Participants

The study involved a sample of 25 fifth-grade participants from a public school located in the Northeastern region of Thailand. The chosen school was a technologically advanced institution with access to the Internet. In addition, prior knowledge about quadrilaterals were needed. That was why they were chosen to be the in this research.

3.3 Research Instruments

In this study, there are two research instruments. The first instrument is a conceptual test involving the conception of the properties of quadrilaterals. The test was adapted from the study of Okazaki and Fujita (2007) about the properties of quadrilaterals. There are five questions in the test. Each question consists of six to eight statements. The participants had to read and fill in the correct symbol if they think that statement is correct, the cross symbol if they think it is incorrect and the question mark symbol if they are not sure. In the first question, there are eight quadrilateral figures, the students are asked, which are parallelograms. Second question, there are six quadrilateral figures, the students are asked which are rectangles. The third question, there are six quadrilateral figures, the students are asked which are squares. The fourth question, there are six statements about properties, the students are asked about the properties of parallelograms. The fifth question, there are five statements, regarding the properties of rectangles, and in the last question, there are five statements, regarding the properties of squares. The second instrument is an attitude questionnaire regarding the use of technology to learn mathematics. A 5-point Likert-scale survey is being used to examine student attitudes. It consists of 20 questions covering four each on mathematics confidence (MC), four each on technological confidence (TC), four each on attitude towards using technology to learn mathematics (MT), four each on affective engagement (AE), and four each on behavioral engagement (BE). The following subscale reliability levels are indicated by Cronbach's alpha values: MC, 0.87; MT, 0.89; TC, 0.79; BE, 0.72; and AE, 0.65. Pierce et al.'s (2007) questionnaire was used to create this.

3.4 Data Collection and Analysis

The data collection of this research is shown in the figure 1. Before the approach, the students were given 20 minutes to do the pre-test of conceptual understanding and attitude questionnaire. After completing the instruments, they were expected to interact with a mobile-supported board game with inquiry-based learning, which consists of three phases: First phase, Pre gaming phase begins with open-ended questions and provides basic information about quadrilateral that students can use in the next step. Second, Gaming phase is a learning process through a quadrilateral board game with mobile phone to find answers to the first open-ended questions. Third phase, Post gaming phase is a summary of knowledge gained in answering those open-ended questions together. After finishing the learning process, students were administered the same questionnaires again for 20 minutes to determine their conceptual understanding and attitude toward mathematics learning with technology.

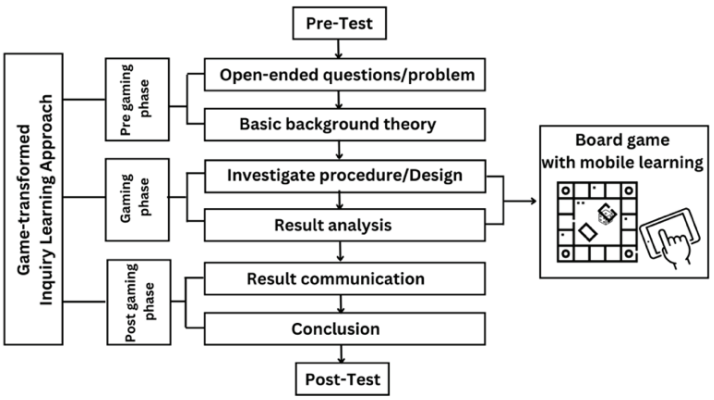

Figure 1. An illustration of the experimental procedure of this study.

The data collection process took one week (5 periods, 250 minutes) of which the first two periods consisted of a pre gaming phase in which open-ended questions and background theory were provided.

3.5 Learning Material

The game carried on round by round. Firstly, each student began by picking up a question card. Then, they answer the questions on that card and scan a QR code to check the answers. If they got the answer right, they would get one coin. The coins could be collected for winning the game in case nobody won in the game. After that, each student could decide to follow one of the three directions. To clarify, the first direction is to roll the dice to race the horse. The students had to press the button of the mystery box, which contained five different-colored dices. If the student got the dice in any color, they could move the horse chess which shared the same color forward on the betel table. Also, if the chosen dice showed any number, they could move their dice forward as the same step on the betel table. During the game, the student can choose to either trap or reward their friends by putting +1 or -1 on their track. +1 refers to a step forward, whereas -1 refers to a step backward. Additionally, while playing, the student must bet which horse will win as well. Following the figure 2, With the rules of this game, students will encounter questions for themselves as well as assess the responses of other students regarding the properties of the quadrilateral.

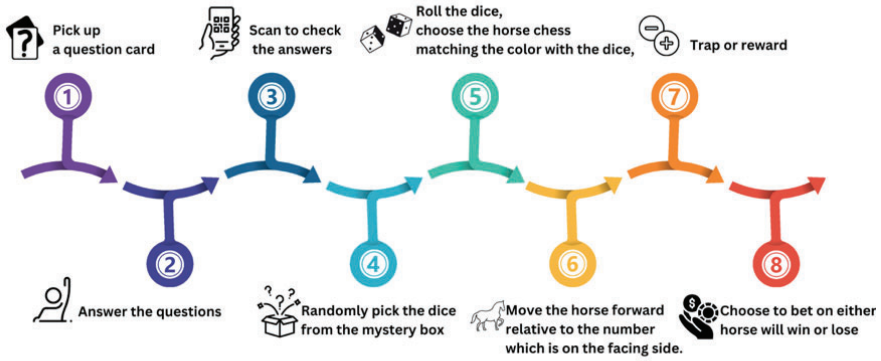

Figure 2. An illustration of gaming steps with the quadrilateral board game.

4. Result and Discussion

4.1 Conceptual understanding of quadrilateral

This study using parametric statistics analysis of paired t-test, a comparison of pre-test and post-test conceptual understanding scores revealed that the post-test score of students' conceptual understanding was significantly higher than the pre-test score ($t=-5.580$, $p<.05$). The statistics the paired t-test are displayed in Table 1.

Table 1. *Paired T-Test Result for Conceptual Understanding on The Properties of Quadrilateral.*

Conceptual Understanding test	N	Mean	S.D.	t
Pre-Test	24	18.17	5.435	-5.580*
Post-Test	24	24.58	6.021	

*p<0.05

As shown in the table above, the results indicate that students' post-test scores are significantly higher than their pre-test scores after using the board game with mobile integrated game-transformed inquiry-based learning approach. Based on the result in this study, students

could improve their conceptual understanding of the properties of quadrilaterals. Regarding the basis of prior research, Nukprach et al. (2023) found that using eye tracking of students when they learnt through the technology-supported board game could promote students' cognitive exertion which increases while playing board games. Hence, integrating board game with technology have been found to effectively aid in the comprehension of mathematical concepts on the properties of quadrilaterals.

4.2 Students' Attitude toward Mathematics Learning with Technology

As shown in the table 2, we can see that it has a statistically significant effect on both mathematics confidence (MC) ($F(1, 24) = 11.565$; $p < .05$; partial $\eta 2 = .335$) and affective engagement (AE) ($F(1, 24) = 7.271$; $p < .05$; partial $\eta 2 = .240$).

Table 2. *The students' subscale means of attitude by time and univariate MANOVA.*

Subscale	Attitude		F	Sig	η^2
	Pre-Test Mean (SD)	Post-Test Mean (SD)			
MC	12.71(2.216)	14.75(2.739)	11.565	.002*	.335
TC	13.50(2.359)	14.54(2.395)	3.968	.058	.147
MT	14.62(3.943)	15.04(3.470)	0.204	.656	.009
AE	13.71(3.277)	15.46(2.859)	7.271	.013*	.240
BE	13.46(2.553)	14.67(2.632)	3.631	.069	.136

*p<0.05

As shown in the table 2, it refers that a board game with mobile is the key to gain students' confidence in learning Mathematics (MC). In other words, mobile-supported board games promote the student's happiness (AE) when they can solve difficult math problems. The findings of this study align with the research conducted by Premthaisong and Srisawasdi (2020) and Lin and Cheng (2022), which explored the integration of technological devices with board games as a pedagogical tool for teaching primary school students is a great tool for teaching students in primary school. Similarly, Hwang and Chang (2011) observed that this instructional approach not only fostered students' interest and attitude towards learning, but also positively impacted their academic achievement. The utilization of mobile learning as a means of evaluating the enhancement of students' attitude and academic performance.

However, some students, who are normally familiar with using physical board games rather than the digital kinds, did not have a great performance and lack confidence in playing mobile-supported board games. Consequently, it resulted the significance value of technological confidence of no less than 0.05. Nevertheless, there are numerous other technologies that can be applied to board games to create mobile-supported board games that promote positive attitudes and academic achievement for students in primary school.

5. Conclusion and Limitation

The purpose of this study is to investigate the conceptual understanding and the attitude toward mathematics learning with technology, of primary school students by using mobile-supported mathematics board game. Based on the findings of this study, we can confirm that the strategy is an effective tool for teaching difficult issues in mathematics learning. Moreover, they have a positive attitude of technology-enhanced mathematics learning with game-based inquiry learning. According to the findings of this study, mobile-supported board games have the potential to foster greater innovation in mathematics classrooms. Due to this study being

conducted in Thailand, it can apply in other developing countries. However, a limitation of this study is the small number of samples, which is a single sample, which makes it impossible to compare conceptual and attitude scores to traditional teaching techniques and gamified inquiry-based learning with mobile learning. Therefore, in future work, there should be comparison group to ensure the learning gains because of this approach.

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