

A DEVELOPMENT OF THE FUNDAMENTAL MATH BOARD GAME FOR ENHANCING THE FOURTH-GRADE THAI STUDENTS' ARITHMETIC ACHIEVEMENT AND MOTIVATION

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ABSTRACT

Nowadays, one effective learning method is board game-based learning, which is particularly appealing to fourth-grade Thai elementary students. This research and development (R&D) study, grounded in the design thinking approach and game-based learning principles, aimed to develop a fundamental math board game on addition, subtraction, multiplication, and division to enhance the arithmetic achievement and motivation of fourth-grade Thai students through the design thinking approach. For this purpose, researchers investigated the effects of a fundamental math board game on the academic achievement and experience of the fourth-grade Thai students. The developed board game, based on the concept of design thinking, was evaluated by three academic experts, who rated its instructional quality as high level ($\bar{x} = 4.61$, $SD = 0.15$). Thirty-six fourth-grade students from Thanyasit Silpa School, participating in the second semester of the 2024 academic year, were selected through a Cluster sampling method to learn fundamental mathematics using this board game-based approach. Researchers collected all data, consisting of pretest and post-test achievements and performances, to be analyzed. The results of a dependent t-test comparison indicated that the students' post-test scores ($\bar{x} = 16.75$, $SD = 1.83$) were significantly higher than their pretest scores ($\bar{x} = 7.11$,

SD = 2.14). Additionally, the students expressed high satisfaction with the learning experience ($\bar{x} = 4.75$, SD = 0.52). These findings confirm that the developed fundamental math board game effectively enhances academic achievement and attracts interest in math learning for fourth-grade Thai students, and suggest that the developed boardgame can serve as an effective pedagogical tool for enhancing arithmetic competency and fostering motivation in elementary mathematics education.

Keywords: Board game, Fundamental mathematics, Design thinking approach, Arithmetic achievement, Learning motivation

I. INTRODUCTION

In today's educational landscape, the mathematics field is an essential subject for the digitally aged elementary students. It is the essential core of STEM (Science, Technology, Engineering, and Mathematics) components, providing the logical framework, problem-solving skills, and analytical tools necessary to understand and apply concepts across science, technology, and engineering. Especially, the arithmetic skill is the essence of fundamental mathematics. It enables precise analysis and communication of ideas, fosters critical thinking, and facilitates the development of solutions to real-world challenges. The Arithmetic is widely acknowledged by educators and researchers as essential across all academic subjects to enhance student performance in the current generation that the one competency of the 21st-century skills refer to the 3R8C framework in Thailand, which includes Reading, wRiting, aRithmetic, Critical thinking, Creativity, Cross-cultural understanding, Collaboration, Communication, Computing, Career and learning, and Compassion skills (Poonputta & Nuangchalerm, 2024, pp. 98-113). Despite, the National council of Thailand has included Arithmetic skill as a needed competency of Thai students in the National Scheme of Education B.E. 2560-2579 (2017-2036) (Office of the Education Council, 2017) and promoted as the future skill of the 21st-century world (Office of the Education Council, 2022), the dilemmas of mathematics education seem the decline of student performances in mathematics over time. PISA Thailand (2020, pp. 1-68) reported that the proportion of Thai students at higher benchmarks decreased dramatically while the proportion of the low performers increased, and half of the students may not attain the international basic level of mathematics because of a too low Mathematics score in the national test (O-NET). Despite the importance, Arithmetic skill which is the fundamental mathematics such as addition, subtraction, multiplication, and division operators for fourth-grade students that lays the groundwork for more complex topics, such as fractions, decimals, and area measurement, many students have found a lack of motivation in elementary school caused by a lack of learning method that can attract the elementary students' interest. Sappaile (2024, pp. 1-13) reported his gamification method, which incorporated game elements such as points, levels, and challenges, resulting in greater increases in elementary students' interest, engagement, and overall motivation. Meanwhile, Nguyen et al. (2024, pp. 1-12) reported the effectiveness of STEM education using board games for senior high school students in Vietnam, suggesting that teachers should integrate board games into STEM education to enhance student engagement and understanding of STEM concepts. Consistent with the researcher's study results that we studied and surveyed a problem in the mathematics



class of fourth-grade students from Thanyasit Silpa School in Pathum Thani province, and found a low achievement problem, specifically the students' lack of Arithmetic competency, which is a basic fundamental of Mathematics. Almost all respondents were unable to solve problems using basic mathematical operations, such as addition, subtraction, multiplication, and division, and found the traditional lecture method boring.

Lack of motivation in learning, which adversely affects academic achievement, has been the subject of ongoing research and experimentation by teachers, psychologists, and educational scholars. Various concepts and methods have been employed to address this issue. A review of the relevant literature highlights a learner-centered approach grounded in constructivist principles, conceptualizing the learning process as primarily driven by learners' motivation and enthusiasm. According to this approach, teachers should promote peers' interaction in the classroom within the social context, provide opportunities for practice, facilitate problem-solving of real-world issues, and respond to genuine questions to meet learners' authentic needs (Akpan & Beard, 2016 pp. 392-398; Zajda, 2021 pp. 35-50). Especially among Thai primary school students, numerous research studies support teachers in transforming traditional lecture-based instruction by incorporating active learning through various classroom activities. Such approaches aim to promote a student-centered learning process that enhances student satisfaction and effectively increases academic achievement. Board gaming is a popular activity that several researchers have specifically developed to effectively enhance achievement across various subjects while increasing students' satisfaction more than traditional lecture methods (Punkajab et al, 2023, pp. 141-155; Supandhi et al, 2022, pp. 494-499; Wongchai & Sawangmek, 2023, pp. 49-63).

Researchers developed a board game through the design thinking approach to gain a deep understanding of students' needs, resulting in creative and valuable games that reduce the risk of unreceived products and create opportunities for students to co-develop rules through systematic experimentation and refinement. The design thinking approach is generally defined by many designers as an analytic and creative process that engages a person in opportunities to experiment, create, and prototype models, gather feedback, and redesign through five processes, including emphasize, define, ideate, prototype, and test processes (Razzouk & Shute, 2012, pp. 330-348). The suitability level evaluation form was conducted by researchers under the guidance of their advisor to assess the quality of a prototype using a five-level Likert scale questionnaire, as evaluated by three academic experts. During the experimental period, researchers employed a pretest-posttest design to compare academic achievements using a t-test dependent statistics analysis before and after the intervention. Researchers collected Satisfaction data using a five-level Likert scale questionnaire after the intervention.

This R&D research aims to develop a fundamental math board game using the design thinking approach and to evaluate its impact on fourth-grade Thai students' arithmetic achievement and learning motivation, including its impact on mathematics academic achievement, and the satisfaction data of fourth-grade participants from Thanyasit Silpa School in Pathum Thani province, who learnt the mathematics on addition, subtraction, multiplication, and division using a fundamental math board game that developed by the researcher.

II. LITERATURE REVIEW

The rapid technological, industrial, and social changes in this digital era have led to a shift in global education policies, focusing on STEM: Science, Technology, Engineering, and Mathematics, for widespread research in this decade (Maass et al., 2019, pp. 869–884). Despite mathematics being the prior component of STEM, the role of mathematics in STEM classroom research is still less than that of others. Just & Siller (2022, p. 629) systematically reviewed over 1,900 articles from three popular publication databases, including WOS, ERIC, and EBSCO, and found that only fourteen articles studied the role of mathematics in the secondary classroom. Meanwhile, some educators discussed the role of mathematics in STEM education, including arithmetic competence, which is considered a fundamental mathematics skill that all new generation students need to acquire in order to be successful in the near future. Despite, different vague definitions of 21st-century skills were little vary, almost its was divided by the Partnership for 21st-century Skills (2009, pp. 1-9) into four categories including 1) basic subjects, 2) learning and innovation skills, 3) information, media and technology skills, and 4) life and career skills (Partnership for 21st-century Skills, 2009, pp.1-9; Bircan & Çalışıcı, 2022, pp. 87-119). In Thailand, the 3R8C framework of 21st-century skills consists of reading, writing, arithmetic, critical thinking, creativity, cross-cultural understanding, collaboration, communication, computing, career and learning, and compassion skills, which were wildly acknowledged (Panich, 2012, pp. 1-21; Poonputta & Nuangchalerm, 2024, pp. 98-113). Arithmetic competence directly involves the fundamental mathematics, especially the basic operations, including addition, subtraction, multiplication, and division. Although the Office of the Education Council (2017) promoted arithmetic as a needed future skill in the 20-year National Scheme of Education, PISA and TIMSS reported the critical dilemmas of mathematics education in Thailand, which showed that Thai students had too low mathematics achievement in the national and international tests (PISA Thailand, 2020, pp. 1-68). It is undeniable that the lack of basic mathematics skills at the elementary school level causes many secondary students to encounter problems and obstacles in learning mathematics at higher levels, including mathematical applications across science, technology, and engineering fields. The causal factors include that primary students did not realize the importance of basic skills and knowledge of mathematics that are crucial for future applications at higher levels, and they often think that mathematics problems are too complicated and tedious. At the same time, traditional teaching methods did not motivate them enough. What approaches can solve this dilemma, starting from elementary school mathematics? Board game-based learning has been mentioned as an effective tool for implementing STEM education, with outcomes including cognitive achievements and motivation, especially in primary students (Cardinot et al., 2022; Vita-Barrull et al., 2023; Hashim et al., 2024; Nguyen et al., 2024).

Researchers selected the design thinking approach, which includes the processes of emphasize, define, ideate, prototype, and test, to design and develop a board game's prototype in this study. Razzouk & Shute (2012, pp. 330-348) identified the user-centered features and characteristics of the design thinking approach that are suitable for determining the thinking process of creating a mathematics board game. This approach engaged all stakeholders, including mathematics teachers and fourth-grade students, to explore overall perspectives on needs and expectations through a survey method. Nagai & Taura (2017, pp. 115–133) agreed



and found that the design thinking approach encourages creative exploration. Moreover, prior research highlights persistent deficiencies in Thai students' arithmetic skills, the pedagogical value of learner-centered constructivist environments, and the proven benefits of board game-based learning in enhancing engagement and cognitive performance. These converging insights underscore the necessity of developing a design thinking-driven board game tailored to fourth-grade learners' needs. Therefore, in this study, researchers aimed to develop a suitable fundamental math board game for addition, subtraction, multiplication, and division to enhance the arithmetic achievement and motivation of fourth-grade Thai students through the design thinking approach.

III. RESEARCH METHODOLOGY

This R & D research aimed to develop a fundamental math board game on Addition, Subtraction, Multiplication, and Division for the fourth-grade Thai students through the design thinking approach, as five processes as follows: 1) Emphasize, 2) Define, 3) Ideate, 4) Prototype, and 5) Test.

In the Emphasize process, the beginning of design stage, researchers examined all theories and concepts related to addition, subtraction, multiplication, and division in mathematics subjects in conjunction with the Basic Education Core Curriculum in 2008, revised in 2017, for fourth-grade Thai elementary students (Office of the Education Council, 2017, pp.56-59). Researchers surveyed and interviewed 30 fourth-grade elementary students from Thanyasit Silpa School to identify their mathematical problems using a cluster sampling method. The results showed that they lacked interest and achievement in addition, subtraction, multiplication, and division in mathematics subjects, especially in the division proposition. Therefore, researchers and teachers focused on developing the mathematical board game to facilitate learning and solve this problem. Researchers analyzed and considered the mechanisms and systems of several educational and mathematical board games, including Game Math 24, UNO, and Head Full of Numbers. All possible ideas were discussed with the mathematics teacher, academic experts, and researchers to draft the characteristics of a board game that would appropriately target the fourth-grade Thai students.

In the Define process, two dimensions, including 1) teachers' instruction and 2) students' perception, were defined by researchers and advisors. The results of the survey and observation were as follows: 1) The Instruction of the fourth-grade mathematics: The main problem was the condensed instruction and limited time period, which made it difficult for fourth-grade students to keep up and fully understand the content in the classroom. The students' attention factor is the most important one that causes many students to become bored with traditional lecture activities. Moreover, we found that the math classroom in the afternoon clusters requires an active learning strategy to stimulate the young fourth-grade Thai students more effectively than the morning clusters, which are often fatigued. 2) Students' perception: The findings showed that the fourth-grade samples mostly lacked the division's performance (75%). Meanwhile, 15% of them also demonstrated a lack of proficiency in multiplication. Many students did not pay attention and intend to learn and practice the addition and subtraction operations from the beginning. Therefore, they cannot understand and lack the advanced and complex content, such as multiplication and division.



In these Emphasize and Define processes of designing stage, all intensive data collection through qualitative methods to achieve profound elementary students' insight, where the collected data is synthesized and analyzed to arrive at a definitive and actionable problem articulation.

In the development stage which started with the Ideate process, researchers presented a variety of storyboards and scenarios to academic experts and advisors for advice. Finally, the designed characteristics are illustrated in Table 1.

Table 1: The characteristics of a math board game for the fourth-grade Thai students.

Characteristics	
Type of game:	A collaborative game for two to six physical players to play for around forty minutes per game.
Physical tools:	One set of a math board game, including: 1) two big bingo boards (8x8), 2) players' coins (six colors), 3) a deck of sixty-four proposition cards, 4) a deck of extra cards (thirty punishment cards and seven command cards), and 5) six mini-whiteboards.
Theme:	Role-play with the Halloween theme
Levels:	1. Level 1: Addition, Subtraction, and Multiplication practices 2. Level 2: Division practices
Rules:	1. Player shuffle sixty-four cards in the Q1 deck of level 1. 2. Player shuffle thirty punishment and seven extra cards in the Punishment Deck. 3. All players must play level 1 with the level 1's bingo board and Q1 deck before changing to level 2's bingo board and Q2 deck instead when level 1 finishes. 4. In the first round, all players start with five cards in hand. Everybody considers collecting two preferred cards in their hands and sending the remaining three cards to the next player, until the first player receives the final three cards from the last player, at which point the game is ready. 5. Whoever can put completely his/her four of their coins in a line on a big bingo board will be the winner, or the game will be over when nobody wins.
Mechanism:	1. Level 1, when all players have five initial cards in hand, the game is ready to play. 2. The first player selects and opens his/her one in-hand card to calculate in one minute and speak the answer on time. If his/her answer is correct, he/she can put his/her colour coin on a matched result number's position of the bingo board and pick one new card from the top of the Q1 deck to finish their turn. 3. The second player and following players play the same as the first player until the winner can make a bingo with his/her four coins in a line of any direction on a big bingo board, or no winner if no cards are in the proposition deck. 4. In case any player's answer is incorrect, they must draw a punishment card from the punishment deck and take a rap before finishing his/her turn. However, if they draw an extra card from a punishment deck instead, they can select the special act followed by the card's condition. 5. If someone wins the level 1 bingo board with their four coins in a line, all players will restart the level 2 game with the Q2 card deck and level 2 bingo board.
Hints:	* Allow players to use a whiteboard to calculate their propositions while playing.

In the Prototype process, all suggestions and comments were considered to revise the prototype's mechanism and rules before the researchers developed the prototype and instructions. A set of the math board game and card examples is illustrated in Figure 1. During the development stage of both the Ideate and Prototype processes, researchers employed techniques for conceptualization and idea generation, aiming for maximum creativity and quantity. The most promising concepts were then materialized in the Prototype process, which

is characterized by rapid construction of testable artifacts before committing significant resources.



Figure 1: A set of the math board game and card examples

In the Test process, which encompassed both Validation and Assessment of this solution, these processes inherently covered actions including checking the functionality and usability of the prototype through expert and user trials, ensuring the solution is robust and intuitive, and refining the solution's overall success in addressing the original defined problem and goal. The prototype math board game was qualified and evaluated as a research instrument by three academic experts, yielding an average rating of the highest quality level ($\bar{x} = 4.60$, $SD = 0.57$). Researchers considered all comments and recommendations from stakeholders to improve the released prototype.

Researchers developed and validated all research instruments as follows: 1) a set of math board game prototypes, 2) a suitability assessment questionnaire, 3) achievement tests, and 4) a satisfaction questionnaire. Therefore, after a final prototype was done, researchers conducted a suitability assessment form and presented it to the advisor for verification, along with suggestions and recommendations for improvement. Three academic experts specializing in teaching, measurement, and evaluation assessed the content validity using the IOC (Item-Objective Congruence) index rating. Researchers collected all quality feedback to improve the form. Meanwhile, researchers developed eighty test items to serve as a bank of items for assessing pretest and post-test achievements.

Three academic experts in mathematics assessed the content validity of all items using the IOC index rating, thirty (30) items shown an IOC index from 0.67 to 1.00, and researchers selected qualified items to create an achievement test for a thirty-trial group (30) of fifth-grade elementary students who had passed the mathematics course in the previous semester. Researchers analyzed all qualification values of the test, including a difficulty (p) value (0.2-0.8), a discrimination power (r) value (0.2-0.8), and the reliability of the test form, as determined by the KR-20 formula (>0.8). The results shown a difficulty value (p) ranging from 0.404 to 0.629 and discrimination power (r) ranging from 0.361 to 0.750. The reliability, calculated using the KR-20 formula, was found to be high at 0.820.

Finally, at the end of this step, a satisfaction questionnaire was developed and qualified through three academic experts. All satisfaction questions were assessed for content validity by the IOC index rating of three experts. The fifty-five (55) satisfaction assessment items also showed an IOC index from 0.67 to 1.00.

The population of this study consisted of fourth-grade elementary students from Thanyasit Silpa School in Prathum Thani Province, Thailand, who were enrolled in the second academic semester of 2024, totalling two-hundred and sixty-three (263) students across seven sections (aged between 9 and 11 years old). One section (section 4/6) included thirty-six (36) samples that participated in the examination by the clustering sampling method as the representative group of six homogenous sections. Thanyasit Silpa School and the mathematics teacher granted permission to collect research data. For ethical reasons in human research, all participants under eighteen years old and their parents were informed of the experiment and voluntarily consented before the intervention.

In the Oriental session, all participants took the pretest examination before the experiment began. During the game session, the teacher divided all the students into six groups. All groups studied the math board game mechanics and rules through animation media and an instruction manual for fifteen (15) minutes before playing. Meanwhile, all participants played a math board game for two (2) hours, and all qualitative and quantitative experience data were observed and collected by notes. When all games finished, all participations took the post-test examination, and finally researchers interviewed all participants and requested them to reflect on their attitudes through the satisfaction questionnaire. Researchers collected all the data for analysis. Some experimental atmospheres are illustrated in Figure 2.



Figure 2: Experimental atmospheres

IV. RESULTS

In this section, all results show the suitability level of a fundamental math board game on addition, subtraction, multiplication, and division for the fourth-grade Thai students through the design thinking approach, and the effectiveness on academic achievement and satisfaction of the fourth-grade Thai students is as follows;

The suitability level of a fundamental math board game, covering addition, subtraction, multiplication, and division, for fourth-grade Thai students was evaluated by three academic experts for its quality and suitability in five aspects, as shown in Table 2.

Table 2: Suitability level of a fundamental math board game (n=3).

Board game's aspects	$\bar{x}$	SD	Suitability Level
1. Mathematical context	4.58	0.51	Highest
2. Board game design	4.70	0.47	Highest
3. System and mechanism	4.67	0.48	Highest
4. Problem-solving skills	4.38	0.74	High
5. Effectiveness & retention	4.62	0.59	Highest
Total	4.60	0.57	Highest

In Table 2, the overall suitability of the board game was at the highest level ($\bar{x} = 4.60$, $SD = 0.57$). Four aspects met the highest level, namely the board game design ($\bar{x} = 4.70$, $SD = 0.47$), system and mechanism ($\bar{x} = 4.67$, $SD = 0.48$), effectiveness and retention ($\bar{x} = 4.62$, $SD = 0.59$), and mathematics context ($\bar{x} = 4.58$, $SD = 0.51$), respectively. Only the problem-solving skills aspect was high level ($\bar{x} = 4.38$, $SD = 0.74$), with three sub-aspects being high level, including collaboration with peers ($\bar{x} = 4.00$, $SD = 1.00$), problem-solving skills ($\bar{x} = 3.67$, $SD = 0.58$), and daily-life application ($\bar{x} = 3.67$, $SD = 0.58$).

The effectiveness of a fundamental math board game in enhancing academic achievement in addition, subtraction, multiplication, and division for fourth-grade Thai students is demonstrated through a dependent t-test comparison analysis, as shown in Table 3. Prior to conducting a dependent t-test the statistical assumptions were checked. The academic achievement was measured on a continuous scale and the observations were considered independent across pairs. The key assumption of normality by Shapiro-Wilk was checked with no outliers. Therefore, the dependent t-test assumptions were considered met.

Table 3: The dependent t-test comparison analysis (n=36).

Academic achievement	n	$\bar{x}$	SD	T
Pretest	36	7.11	2.14	-23.61**
Post-test	36	16.75	1.83	

This result shows that fourth-grade Thai students improved their academic achievement in fundamental mathematics, specifically in addition, subtraction, multiplication, and division, as indicated by the average Post-test score ($\bar{x} = 16.75$, $SD = 1.83$), which is significantly higher than the average Pretest score ($\bar{x} = 7.11$, $SD = 2.14$). This quantitative finding is strongly supported by the qualitative observations noted during the intervention. The joyful atmosphere and collaborative nature of the game fostered heightened peer interactions, specifically through the activation of cooperative learning mechanisms and co-construction of knowledge. The observed peer assistance, where some students helped their peers solve more challenging propositions (especially division problems at Level 2) by providing hints, serves as a direct manifestation of Vygotsky's Zone of Proximal Development (ZPD). This peer scaffolding is crucial, as it allowed struggling students to master tasks that were initially beyond their independent capability, thereby translating positive social interaction into concrete cognitive gains and ultimately, improved academic achievement.

The satisfaction of the fourth-grade Thai students who learnt through a fundamental math board game on addition, subtraction, multiplication, and division, as shown in Table 4.

Table 4: Satisfaction level of a fundamental math board game (n=36).

Board game's aspects	$\bar{x}$	SD	Satisfaction Level
1. Board game design	4.74	0.53	Highest
2. Mathematical content	4.76	0.51	Highest
3. Board game-based learning	4.72	0.54	Highest
4. Mechanism	4.79	0.44	Highest
5. Outcomes	4.76	0.51	Highest
Total	4.75	0.52	Highest

This table shows that the satisfaction of fourth-grade Thai students achieved the highest overall score on a fundamental math board game ($\bar{x} = 4.75$, $SD = 0.52$). All of sub-aspects was highest level including of the mechanism ($\bar{x} = 4.79$, $SD = 0.44$), mathematical content ($\bar{x} = 4.76$, $SD = 0.51$), outcomes ($\bar{x} = 4.76$, $SD = 0.51$), board game's design ($\bar{x} = 4.74$, $SD = 0.53$), and board game-based learning ($\bar{x} = 4.72$, $SD = 0.54$), respectively. Board game-based learning fostered higher levels of student satisfaction, which resulted in a significantly greater increase in fourth-grade students' intrinsic motivation, willingness, and effort compared to traditional exercises. This effect was qualitatively substantiated by observations that participants calculated mathematical propositions more easily and with superior focus during the game intervention than during homework or assignments.

V. CONCLUSION AND DISCUSSION

The design thinking approach including emphasize, define, ideate, prototype, and test processes, that focused on understanding the needs of fourth-grade Thai students allowed developers gain insights into the actual needs, preferences, and challenges faced by participants, resulting in a fundamental math board game that were more responsive to participants and the highest suitability level ($\bar{x} = 4.60$, $SD = 0.57$) from evaluators in overall aspects including board game design, system and mechanism, effectiveness and retention, mathematical context, and problem-solving skills aspects. When researchers experimented the effectiveness of a fundamental math board game with thirty-six fourth-grade Thai participants, the results showed that all participants developed their academic achievement in fundamental mathematics on addition, subtraction, multiplication, and division as indicated by the average post-test score ($\bar{x} = 16.75$, $SD = 1.83$), which is significantly higher than the average pretest score ($\bar{x} = 7.11$, $SD = 2.14$). Moreover, this fundamental math board game achieved the highest satisfaction level ($\bar{x} = 4.75$, $SD = 0.52$) in all aspects, including its mechanism, mathematical content, outcomes, design, and learning through board games.

The user-centered approach of design thinking processes helped researchers to develop a suitable fundamental math board game for the needs of fourth-grade Thai students, according to Micheli et al. (2018, pp. 124-148), who explored the perspectives of research educators who identified perspectives of scholars writing about design thinking, and provided detailed recommendations for relevant topics warranting further study in order to advance theoretical understanding of design thinking and test its applications. The results confirm the success of



using design thinking approach to develop a fundamental math board game, achieving high suitability and satisfaction, and leading to a significant improvement in academic achievement. This effect is explained by the process's ability to precisely meet the fourth-grade students' psychological and intellectual needs, thus effectively mediating the necessary intrinsic motivation and learning effort for cognitive mastery. Through the examination of complex problems and creative brainstorming, designers developed new ideas for game mechanics, rules, and content to create unique and engaging experiences for participants. The effectiveness of a developed fundamental math board game in the mathematical academic achievement increasing significantly after the intervention, confirmed that fourth-grade Thai students developing their learning process while playing a fundamental math board game, in line with Noda et al. (2019, pp. 1-21) examined the effectiveness of board games through the systematic review method of seventy-one studies, that board games have positive effects on three dimensions, including educational knowledge, cognitive functions, and others. In Thailand, many educators developed the board game-based learning to promote Thai students' achievements including Punkajab et al. (2023, pp. 141-155) developed the card game to promote reading skills of upper elementary school students who lacked of vocabulary scores, and the result showed card game would be increased efficiency of reading skills to remember Thai vocabulary, Supandhi et al. (2022, pp. 494-499) developed a board game as supplementary material for students to learning English grammar very well and fun, they shown the board game model was proper to improve grammar ability of the senior high school students in learning English grammar, or Wongchai and Sawangmek (2023, pp. 49-63) developed the guidelines for adaptive learning management with board games for enhancing learning progress in science of the fourth-grade students in Phrae Province, and reported the students have made more progress in learning science after learning adaptive learning management with board games. Additionally, board game-based learning would enhance the interpersonal interactions and learning outcomes of participants, which would attract youth students. The joyful atmosphere made them satisfied with practicing and learning, as evidenced by the results, which found that a fundamental math board game met the highest level of satisfaction ($\bar{x} = 4.75$, $SD = 0.52$) among the fourth-grade Thai participants. In line with Christian and Prasida (2018, pp. 78-88), who employed a mixed-methods study to develop a board game as learning media for waste sorting awareness among Indonesian fourth-grade elementary students, their study revealed that nearly all fourth-grade students showed greater interest in learning through a board game. So, the game-based teaching is the one of the most effective methods that provides a stress-free environment for children and suits for increasing students' interest in learning, especially the educational board games (Barekat, 2023, pp. 68-75), in line with Nguyen et al. (2024, pp. 1-12) who found the board game-based learning was fit in the delivery of STEM education to increase students' motivation and achievement. Therefore, this research's findings confirm that a developed fundamental math board game, created through the design thinking approach, effectively enhances academic achievement and attracts interest in math learning among fourth-grade Thai students. Nevertheless, several contextual and methodological limitations of this study must be acknowledged. Specifically, the limited sample size ($n=36$) and the brief intervention duration (2 hrs.) pose constraints. These factors may restrict the generalizability of the findings, suggesting that the results should be interpreted



with caution regarding their direct application to larger, diverse elementary student populations or long-term academic improvement. Future research should address these limitations by utilizing a larger, more diverse sample population and extending the intervention duration to several weeks or a full academic semester. This will allow for a more robust assessment of the boardgame's long-term efficacy in terms of knowledge retention and the sustainability of increased intrinsic motivation. Beyond the successful creation of this board game, the Design Thinking approach offers a high-potential framework for driving comprehensive instructional innovation across Thai elementary education. Its application represents an investment in a creative, iterative process that guarantees resulting innovations will exhibit high suitability, effectively foster satisfaction, and ultimately lead to sustainable improvements in academic achievement.

SUGGESTION

During the intervention, researchers observed and noted the effects of various 21st-century skills in fourth-grade Thai participants as they attempted to solve math problems through a board game, including critical thinking, problem-solving, and collaboration skills, while assessing situations, planning strategies, and making rational decisions. Board game-based learning can enhance more essential skills that encourage students to think outside the box, find solutions, communicate, and negotiate with peers to win the game. In the future, researchers may extend these observations to study the effectiveness of board game-based learning in developing related 21st-century skills in elementary Thai students.

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