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# Combining Game-Based Learning with Design Thinking Using Block-based Programming to Enhance Computational Thinking and Creative Game for Primary Students

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**Abstract**

This research aims to develop a combining game-based learning with design thinking using block-based programming to enhance computational thinking and creative games for primary students and will be referred to as game-based learning from now on. The purpose of this research is to 1) develop a model for game-based learning, 2) develop the system for game-based learning, 3) evaluate students' computational thinking after implementing game-based learning, and 4) evaluate the creative games created by students after game-based learning is implemented. The research tools included 1) the model for the game-based learning, 2) the model-appropriate evaluation form, 3) the learning system evaluation form 4) the computational thinking evaluation form, and 5) the creative game evaluation form. The research results showed that 1) the evaluation results of the model are appropriate for teaching at the highest level ($\bar{x}$ = 4.82, SD = 0.42) and could be used for experimental teaching, 2) The results of game-based learning system quality are at the highest level ($\bar{x}$ = 4. 57, S.D. = 0. 50). The researcher implements a game-based learning model and system to teach a sample group of 24 students in grade 4, using a purposive sampling method. The results of the implementation could be summarized as follows: 1) the results of students' computational thinking evaluation after implementing the model and system are significantly higher than before at the .05 level. 2) evaluation results of creative games that students developed after implementing the model and system are at a high level ($\bar{x}$ = 4.29, S.D. = 0.52)

**Keywords**: game-based learning, design thinking, block-based programming, computational thinking, creative games

## 1. Introduction

The competitiveness of 64 countries ranked around the world in 2023, Thailand was at 30th (International Institute for Management Development: IMD, 2030). The ranking of the World Economic Forum (WEF, 2019) found that the overall competitiveness of Thailand compared to emerging and developing ASIA is shown in Figure 1.

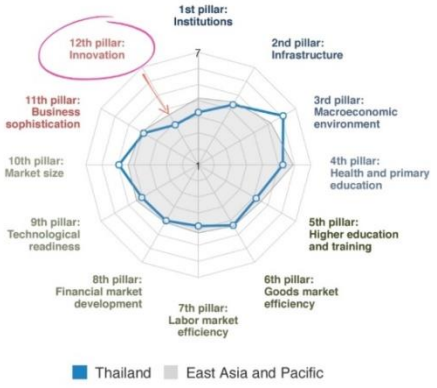


Figure 1. World Economic Forum's Competitiveness Report

As shown in Figure 1, Thailand's score is the lowest in innovation, indicating that Thailand needs to focus on developing this skill to become an innovation-driven country to escape the trap of being a middle-income country. Innovation is one important way to improve the middle-income trap. Learning programming from a young age is one method to develop innovation which is an essential skill to survive in the 21st century (P21, 2016). Using computer software helps to develop creativity and the ability to solve problems (problem-solving), which is the most important starting point for creating innovations to increase the country's competitiveness. Currently, the Ministry of Education has included subjects to teach each student to practice computer programming skills and the use of information communication technology in a computational science subject, established in the basic education core curriculum in 2017, and becomes compulsory in May 2018 for primary school to high school. Teaching computational science subject is aimed at developing students's computational thinking skills, but there are not enough teaching models for teachers to make students interested in and have fun with learning programming. The researcher has an idea to develop game-based learning to promote computational thinking and creative games for primary students. Developing an alternative model, the researcher analyzes the knowledge of game-based learning and design thinking, synthesizes them into a learning process, and develops a combining game-based learning with design thinking using block-based programming to enhance computational thinking and creative games for primary students' model. This will refer to combining game-based learning with design thinking from now on. The research aims to

1) develop the model for combining game-based learning with design thinking.

2) develop a system for combining game-based learning with design thinking.

3) evaluate students' computational thinking after combining game-based learning with design thinking is implemented.

4) evaluate students' creative games after combining game-based learning with design thinking is implemented.

## 2. Research Questions

According to the research purpose, we take research questions for

1) The results of evaluating the appropriateness of the model for combining game-based learning with design thinking.

2) The results of evaluating the quality of the system for combining game-based learning with design thinking.

3) The results of evaluating students' computational thinking after combining game-based learning with design thinking model and system are implemented.

4) The evaluation results of the creative games that students created after combining game-based learning with design thinking model and system are implemented.

## 3. Related Works

Game-based learning refers to the use of games, whether digital or non-digital, as educational tools to facilitate learning and skill development. According to Boonpienpon (2021), there are 5 steps in game-based learning: 1) set the learning objective 2) plot the game 3) explore the learners' opinions towards the game 4) improve and develop the game 5) evaluate game-based learning management. Design Thinking is the process of creating innovation and solving problems. By focusing on people more than anything else, design thinking isn't about thinking, it's about being a process combined with beliefs that affect behavior and mindset. Design thinking processes are empathizing, defining, ideating, prototyping, and testing (Kittitornkul, 2022). Chommai (2019) refers to block-based programming (instruction program) as programming in a format similar to putting together a jigsaw puzzle or block logo such as SCRATCH or LOGO. Learners do not have to worry about computer language grammar. Computational thinking is a problem-solving approach that draws upon concepts and techniques used in computer science to address complex problems across various domains. Its components are breaking down problems into smaller, more manageable parts, identifying patterns and algorithms to solve them, and using abstraction and decomposition to simplify the problem-solving process (Institute for the Promotion of Teaching Science and Technology, 2017). The criteria for evaluating creative games are divided into 3 groups: 1) game creation concept, 2) level of complexity in programming, and 3) interesting and usable designs (Wilson, Hainey, & Connolly, 2013). The researcher synthesizes the mentioned knowledge to depict a conceptual framework as shown in Figure 2.

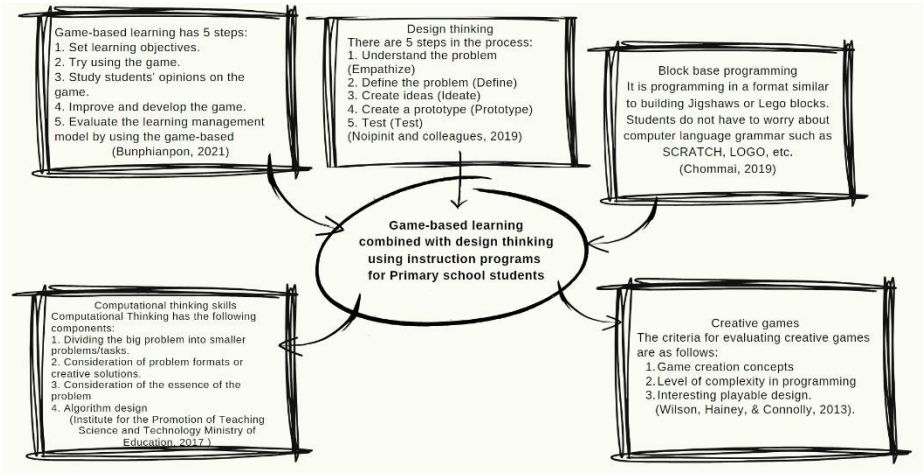


Figure 2. Combining game-based learning with design thinking conceptual framework

## 4. Research Methodology

### *4.1 Population and Sample*

The population is three grade 4 primary classrooms of Wat Rang Kam Yat School in Thailand.

The sample is 24 students from one grade 4 primary classroom, in the second semester of the 2023 academic year, using the Purposive Sampling method.

### *4.2 Experimental Design*

The one-group pre-test & post-test experimental design (Smith, & Johnson, 2021) is used for the analysis of students' achievement in implementing the combining game-based learning with design thinking model as shown in Figure 3.

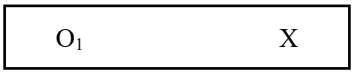


Figure 3. The research plan uses one group pre-test & post-test design

$O_1$ Refers to the test before studying (pre-test)

X Refers to combining game-based learning with design thinking model that has been tried and tested for teaching.

$O_2$ Refers to the test after studying (post-test)

### *4.3 The Tools Used to Collect Data for Combining Game-based Learning with Design Thinking*

Assessment of appropriateness evaluation form for implementing the model: the game-based learning combined with design thinking in primary students. Qualified 7 experts with at least 5 years of experience are invited to evaluate 5 levels of questions as in Table 1.

Table 1. The criteria for interpreting the appropriateness of implementing the model in primary students

| Evaluation Score | Meaning |
|---|---|
| 5 | the highest level of appropriateness |
| 4 | a high level of appropriateness |
| 3 | a moderate level of appropriateness |
| 2 | a low level of appropriateness |
| 1 | the least level of appropriateness |

By finding the mean value and standard deviation of the evaluation scores. The evaluation values are compared with the following criteria for interpreting the results shown in Table 2.

Table 2. The criteria for interpreting the appropriateness of implementing the model in primary students

| Evaluation Score | Meaning |
|---|---|
| 4.51 – 5.00 | the highest level of appropriateness |
| 3.51 – 4.50 | a high level of appropriateness |
| 2.51 – 3.50 | a moderate level of appropriateness |
| 1.51 – 2.50 | a low level of appropriateness |
| 1.51 – 2.50 | the least level of appropriateness |

System evaluation form after implementing the model: combining game-based learning with design thinking. The same evaluation criteria as in Section 4.3.1 are used.

Computational thinking evaluation form after implementing the model: combining game-based learning with design thinking. Using the rubric score evaluation (Popham, 1997) according to the actual situation which is 20 questions with 4 answer options. The criteria for interpreting the meaning of the mean value are in Table 3.

Table 3. The criteria for interpreting the meaning of the mean value

| Evaluation Score | Meaning |
|---|---|
| 16-20 | the highest computational thinking skills level |
| 11-15 | a high computational thinking skills level |
| 6-10 | a moderate computational thinking skills level |
| 0-5 | the least computational thinking skills level |

Creative game evaluation forms after implementing the model: combining game-based learning with design thinking in teaching computational science subjects, three teachers with different roles use this form to evaluate the quality of the games created by 8 groups of students. Using the rubric score evaluation according to the actual situation. Three evaluation criteria aspects are 1) game creation concepts, 2) level of complexity in programming, and 3) interesting playable design (Wilson, Hainey, & Connolly, 2013), using the evaluation criteria in Table 1 & Table 2.

*4.4 Steps for Conducting Research and Collecting Data*

The combining game-based learning with design thinking research is divided into 4 phases as follows:

Analyze theoretical and research concepts then synthesize them into the combining game-based learning with design thinking process table.

Develop the process table in 4.4.1 by combining game-based learning with design thinking model and evaluate the appropriateness of the model by 7 qualified experts with more than 5 years of experience.

Develop the process table in 4.4.1 by combining game-based learning with design thinking model and evaluate the appropriateness of the model by 7 qualified experts with more than 5 years of experience.

*4.5 Statistics Used in Research*

4.5.1 Statistics Used to Determine Research Tool Quality

Check content consistency (IOC) by calculating from the following formula (Itthipat, 2019)

$$IOC = \frac{\Sigma R}{N}$$

IOC is the index of consistency between questions and objectives.

ΣR is the sum of the expert opinion scores.

N is the total number of experts.

4.5.2 Basic Statistics

Arithmetic mean ($\bar{x}$) calculated from the following formula:

$$\bar{x} = \frac{\Sigma X}{N}$$

$\bar{x}$ is the average score.

ΣX is the sum of all scores.

N is the amount of data.

Standard deviation (S.D.)

$$S.D. = \sqrt{\frac{N\sum X^2 - (\sum X^2)}{N(N-1)}}$$

S.D. is the standard deviation.

$\sum X$ is the sum of all scores

$\sum X^2$ is the sum of each sample's squared scores.

N is the number of students in the sample

Reference Statistics to Evaluate Computational Thinking

Compare computational thinking before and after studying, using a dependent samples t-test that is not independent of each other.

## 5. Research Results

### *5.1 The Synthesized Conceptual Framework of Combining Game-based Learning with Design Thinking*

The results are shown in Table 4. The 7 steps start with setting objectives, curiosity build-up, re-learning, activity, testing, criticizing, and holistic assessment.

Table 4. The results of the synthesis of knowledge, the combining game-based learning with design thinking.

| No. | Analyze the steps of game-based learning by the researcher | Analyze the steps of design thinking by the researcher | Combining Game-Based Learning with Design Thinking | Elements of combining game-based learning with design thinking using block-based programming to enhance computational thinking and creative games |
|---|---|---|---|---|
| 1 | Set learning objectives | Empathize | 1. Set learning objectives using games. | The system used for learning<br>1. The Moodle system. |
| 2 | Play the given game, analyze the problems of the game, and learn the content used to create games | Define | 2. Create curiosity by playing given games.<br>3. Analyze and learn programming from games played | (https://dict.fte.kmutnb.ac.th/moodle/login/index.php)<br>2. Scratch program (www.scratch.mit.org)<br>3. Computer or tablet<br>4. Game-based learning lessons with Design thinking with block-based programming to promote computational thinking and creative games |
| 3 | Introduce new game design idea | Ideate | 3. Brainstorm to present game development guidelines. | |
| 4 | Develop the game | Prototype | 4. Create a game and test it. Listen to criticism from presentations of games you create. | 5. Evaluation via Google Form |
| 5 | - | Test | 5 Listen to criticism from presentations of games you create. | |
| 6 | Evaluate by the audience | - | 6. Evaluate by every listener | |

### *5.2 Create a Graphic Model for Combining Game-based Learning with Design Thinking*

The graphic model has been evaluated for appropriateness for primary students as shown in Figure 4.

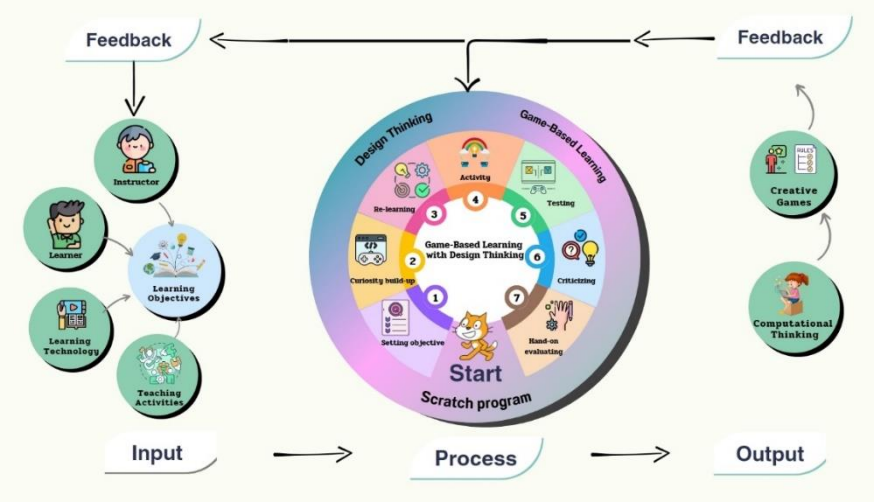


Figure 4. The combining game-based learning with design thinking using block-based programming to enhance computational thinking and creative games for primary school students

Combining game-based learning with design thinking is composed of 4 main components. The details are described as follows.

Input factors that are used as data in designing and developing the combining game-based learning with design thinking are learning objectives which are composed of teaching and learning activities, students, teachers, and technology that promote learning.

The learning process is the internal learning process of combining game-based learning with design thinking. Consists of 7 steps as follows: 1) Setting learning objectives 2) Curiosity build-up: letting students play the given game 3) Re-learning: studying and analyzing program coding from the given game after playing the game. 4) Activity: creating a group working then using the design thinking process to create ideas, present game development guidelines, and create a game 5) Testing: iterative testing of each part of the developed game until the game is complete. 6) Criticized: presenting the game by every student group in front of the room and listening to teachers and other students' opinions to collect feedback data to use for improving the game in the future 7) Holistic assessment: evaluating the creative game by three teachers in three criteria, game creation concepts, level of complexity in programming, and game interested and playable.

Output is the result of the learning process, 1) computational thinking skill which is a process of solving problems by thinking analytically and logically, step by step, to find a solution as mentioned already in section 4., 2) creative game that can refer to a variety of activities or experiences designed to stimulate creativity and imagination in students. It is a way to bring out creativity in students to create a workpiece.

Feedback is the use of information on results from the learning process and output after implementation to improve the quality of the model and system.

The appropriateness evaluation results of combining game-based learning with design thinking are the highest appropriate for all components.

Table 5. The results of evaluating combining game-based learning with design thinking by 7 experts

| Evaluation list | | $\bar{x}$ | S.D. | Appropriate level |
|---|---|---|---|---|
| 1. Input factors | 1.1 Learning objectives | 4.86 | 0.38 | the highest |
| | 1.2 Combining game-based learning with design thinking | 4.86 | 0.38 | the highest |
| | 1.3 Learner roles | 4.71 | 0.49 | the highest |
| | 1.4 Teacher's Role | 4.57 | 0.79 | the highest |
| | 1.5 Technology that promotes learning using block-based programming | 4.86 | 0.38 | the highest |
| 2. combining game-based learning with design thinking | 2.1 Set learning objectives | 4.57 | 0.79 | the highest |
| | 2.2 Create curiosity through learning by playing designated games. | 5.00 | 0.00 | the highest |
| | 2.3 Study and analyze programming methods from the given game after learning. | 5.00 | 0.00 | the highest |
| | 2.4 Brainstorm ideas to present guidelines for creating games. | 4.86 | 0.38 | the highest |
| | 2.5 Create a game by programming instructions and testing the program. | 5.00 | 0.00 | the highest |
| | 2.6 Listen to opinions from game evaluations. and discuss together | 5.00 | 0.00 | the highest |
| | 2.7 Overall evaluation | 5.00 | 0.00 | the highest |
| 3. Results | 3.1 Academic achievement | 4.71 | 0.49 | the highest |
| | 3.2 Computational thinking skills | 5.00 | 0.00 | the highest |
| | 3.3 Creative games | 5.00 | 0.00 | the highest |
| 4. Feedback | Information on results from enhancing computational thinking skills, and creative games feedback to compare with learning objectives and model improvement | 5.00 | 0.00 | the highest |
| Overview | | 4.88 | 0.38 | the highest |
| Combined composition | 1. Game-based learning combined with design thinking with instructional programs to promote computational thinking and creative games for primary school students model | 4.71 | 0.49 | the highest |
| | 2. The conceptual framework covers elements of a game-based learning model combined with design thinking with block-based programming to promote computational thinking and creative games. | 4.71 | 0.49 | the highest |
| | 3. Game-based learning format combined with design thinking with block-based programming to promote computational thinking and creative games. There are consistent and appropriate definitions of terms. | 4.57 | 0.53 | the highest |
| | 4. Sequencing elements in designing game-based learning formats together with design thinking using block-based to promote computational thinking and creative games. Having the right order is continuous and connected. | 4.71 | 0.49 | the highest |
| | 5. Arranging the sequence of elements in a game-based learning format combined with design thinking using block-based programming to promote computational thinking and creative games. It is appropriate and easy to understand. | 4.71 | 0.49 | the highest |
| | 6. Overview of the elements of combining game-based learning with design thinking to promote computational thinking and creative games. It can be used as a guideline for developing the combining game-based learning with design thinking to encourage students to develop computational thinking skills, and creativity within individuals. | 4.57 | 0.53 | the highest |
| Overview | | 4.67 | 0.48 | the highest |
| Total | | 4.82 | 0.42 | the highest |

From Table 5, it is found that the overall appropriateness of the development of combining game-based learning with design thinking is at the highest level ($\bar{x}$ = 4.82, SD = 0.42). In conclusion, the model can be used to

experiment to teach students in Primary School.

*5.3 The Combining Game-based Learning with Design Thinking System*

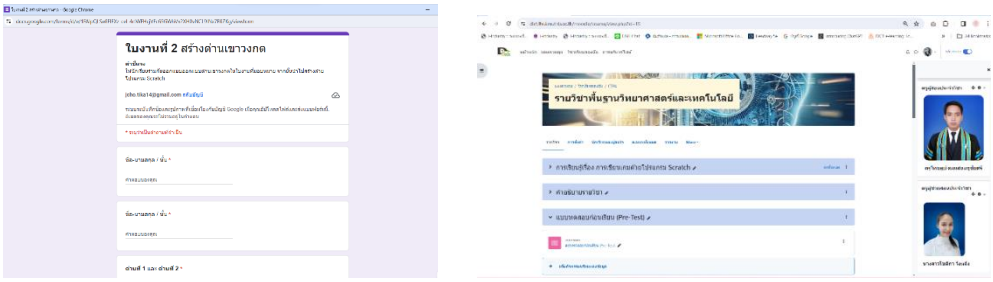


Figure 5. The front page of the combining game-based learning with design thinking system

From Figure 5, the researcher adapts to the use of the Moodle learning management system and uploaded all components of combining game-based learning with design thinking and also the related context data to Moodle LMS as follows:

The learning objectives of the students, when learning ends.

Contents used for teaching in the computational science course: Unit 2, writing a simple program with Scratch. Digital media is used to support learning and teaching material such as video, PowerPoint, and documents for teaching.

Learning management lesson plan to teach the computational science course: Unit 2, writing a simple program with Scratch.

Evaluation form 1) computational thinking evaluation: creating a 20-question multiple-choice test with 4 choices to select for all 4 components of computational thinking. Then setting the linkage of the test on Moodle. 2) creative game evaluation: creating creative game evaluation form for 3 criteria, 1) game creation concept 2) level of complexity in programming 3) interesting design and playable game when executed on the Scratch platform. Then setting the linkage of those evaluation forms on Moodle.

Learning management system members such as computational science teachers and grade 4 students' names to set up the classroom and communication chat board etc.

Block-based programming: set up linkage on Moodle learning management system to use scratch block-based program (https://scratch.mit.edu/)

*5.4 System Quality Evaluation Results on Game-based Learning Combined with Design Thinking Using Block-based Programming*

The results of the System quality evaluation are shown in Table 6.

Table 6. System quality evaluation results of game-based learning combined with design thinking using block-based programming

| number | Evaluation criteria | average | S.D. | Quality level |
|---|---|---|---|---|
| 1 | Learning objectives | 4.45 | 0.51 | a high level |
| 2 | Content | 4.52 | 0.51 | the highest |
| 3 | Learning management plan | 4.48 | 0.51 | a high level |
| 4 | Evaluation form | 4.50 | 0.53 | a high level |
| 5 | Learning management system | 4.57 | 0.50 | the highest |
| 6 | Instruction program | 4.77 | 0.43 | the highest |
| together | | 4.57 | 0.50 | the highest |

From Table 6, it is found that the overall system quality evaluation results of combining game-based learning with design thinking by 5 experts, is at the highest level ($\bar{x}$ = 4.57, SD = 0.50). In conclusion, the system components are complete and can be used for experimental teaching.

*5.5 Computational Thinking Evaluation Results*

By comparing pre-test and post-test scores after learning through combining game-based learning with design thinking model, using a dependent samples t-test has results as shown in Table 7.

Table 7. Results of the computational thinking assessment after the experiment

| | $\overline{x}$ | S.D. | $\overline{D}$ | $S.D._D$ | t | Sig.(1-tailed) |
|---|---|---|---|---|---|---|
| Before learning by combining game-based learning with design thinking | 8.63 | 2.96 | 5.29 | 2.85 | 9.09* | 0.000 |
| After learning by combining game-based learning with design thinking | 13.92 | 3.11 | | | | |

From Table 7, it is found that the results of the evaluation of students' computational thinking after learning through combining game-based learning with the design thinking model are significantly higher than before learning at the .05 level.

*5.6 Creative Game Evaluation after Implementing The Model*

Figure 6 shows examples of games that students have created from a total of 8 games, and every group presents the game in front of the classroom and the game is evaluated, as shown in Table 8.

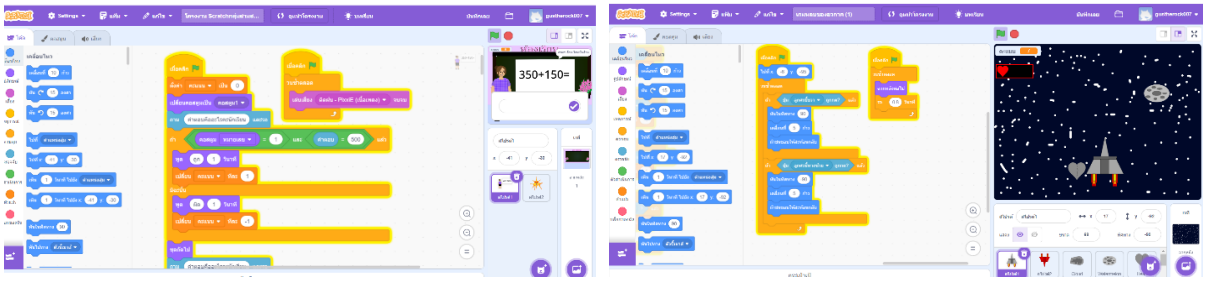


Figure 6. The picture of the 2 games that the students created, named Death Number Addition Game, and Rocket-Game

Table 8. The results of evaluating 8 creative games created by students

| | Evaluation criteria | average | S.D. | Quality level |
|---|---|---|---|---|
| 1 | Game creation concept | 4.23 | 0.53 | a high level |
| 2 | Level of complexity in programming | 4. 25 | 0.36 | a high level |
| 3 | The game is interesting designed and playable. | 4.38 | 0.33 | a high level |
| together | | 4.29 | 0.52 | a high level |

From Table 8, it is found that the evaluation results of the creative games created by students after learning through the combining game-based learning with design thinking model are at a high level ($\bar{x}$ = 4.29, S.D. = 0.52).

**6. Discussion**

The results of the research mentioned in section 5 can be concluded that implementing the combining game-based learning with design thinking through the design learning system can develop students' computational thinking, which is consistent with the purpose of the Institute for the Promotion of Teaching Science and Technology (2017) in developing the subject of computational science and forcing it to be taught in schools across the country, as well as preparing students to have a good attitude towards beginning coding.

The t-test result from Table 7 leads to acceptance of the research purpose that the computational thinking results after experimental teaching through the combining game-based learning with design thinking is significantly higher than before at .05 level, which is consistent with Totan's research results, and Korucu (2023). concluding that block-based coding environments have a huge impact on computational thinking, self-efficacy, and positive attitudes toward learning to code.

For the creative games created by students evaluation results in Table 8, show the development of students' creative games after experimental teaching through the combining game-based learning with design thinking at a high level in three areas: the concept of game creation ($\bar{x}$ = 4.23, S.D. = 0.53), level of complexity in programming ($\bar{x}$ = 4.25, S.D. = 0.36), and an interesting design and playable game ($\bar{x}$ = 4.38, S.D. = 0.33). These results are consistent with Resnick's research, in collaboration with the Lifelong Kindergarten research group of the MIT Media Lab (2003) developed an initiative to promote change in the learning process of students in the Scratch project. The result is that students learn to design, express, and use creativity through technology to create a game

using Scratch. As well as from the research results of Wilson, Hainey, & Connolly ( 2013) who concluded that coding can promote learning among learners to develop creative thinking skills that are necessary for learners in the 21st century.

## 7. Suggestion

Another interesting example is one of the games that students create on their own without any teachers' guidance. The game can be used as mathematics game-based teaching for the elementary school level as shown in Figure 7, which is objective evidence that combining game-based learning with design thinking can be applied to teach and collaborate in other subjects, according to the concept of interdisciplinary which is necessary for the 21st century. For example, teachers can integrate STEM (Science, Technology, English, & Mathematics) teaching concepts by combining game-based learning with design thinking model.

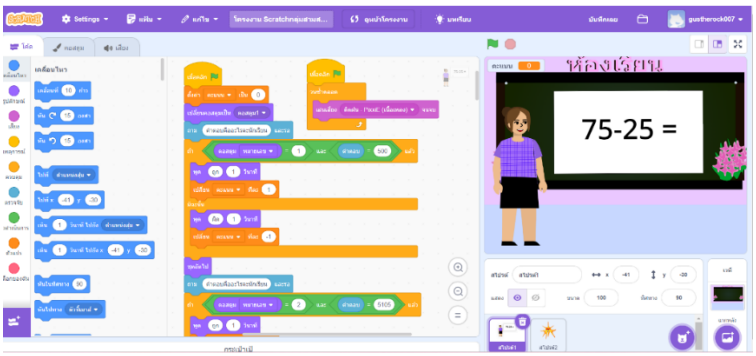


Figure 7. The game that the students created, is named Death Number Addition Game

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## Authors contributions

Chotika Wanglang developed the main idea of this research, wrote the manuscript, developed the research tools, and studied the results. Assoc. Prof. Dr. Kobkiat Saraubon and Prof. Dr. Pallop Piriyasurawong advised to development of the research methodology. Prof. Dr. Pallop Piriyasurawong revised and composed the writing quality of the manuscript, and rechecked the manuscript before it was submitted. All authors approved the final research paper.

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## Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Informed consent

Obtained.

## Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

## Provenance and peer review

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## Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

**Data sharing statement**

No additional data are available.



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