Promoting Computational Thinking Skills Through Game-Based Learning of Students in Lower Secondary School

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***Abstract*— This study's objectives were to: 1) compare computational thinking skills before and after game-based learning activities; and 2) study students' satisfaction after game-based learning. The research methodology uses the ADDIE model by driving game-based learning activities and promoting students with computational thinking skills, including decomposition, pattern recognition, abstraction, and algorithm design. The statistical methods used to analyze the data were mean, standard deviation, and t-test. The study's findings revealed that 1) the students' computational thinking skills improved significantly after engaging in game-based learning activities, demonstrating statistical significance at the.05 level, and 2) the overall students' satisfaction after activities with game-based learning was averaged at the highest level (= 4.75, S.D. = 0.52).**

Keywords—computational thinking skills, game-based learning, learning activity

I. INTRODUCTION

Computational thinking is a core skill that emphasizes the systematic analysis, sequential problem-solving, and resolution of intricate situations [1-3]. The four essential elements of this are decomposition, pattern recognition, abstraction, and algorithm design. The PISA education assessment has indicated that students in Thailand possess comparatively limited levels of analytical thinking, a critical skill for forming the nation's future leaders. As a result, learning management skills are essential for promoting these types of abilities. Teachers should focus on developing learning management strategies to assist students in improving their computational thinking skills, which will necessitate the acquisition of advanced analytical skills [4].

The Institute for the Promotion of Teaching Science and Technology adopts the method of unplugged coding learning to help students improve their computational thinking skills. Teachers have the ability to design classes by using a variety of instructional methodologies, with a focus on encouraging active involvement from students [5-6]. Game-based learning involves using games to actively involve and motivate students, promote collaboration, and enhance their learning experience in an enjoyable and stimulating setting [7]. This learning approach is effective as the instructor presents a problem scenario or a case for the student to develop skills in thinking, analysis, problem-solving, and self-reliance, all while engaging in the activity without considering it a formal learning experience [8]. The objective of this method is to enhance student behavior by improving their knowledge, abilities, and attitudes through a student-centered approach to managing their learning [9].

Thus, the researchers highlighted the need for developing students with computational thinking skills, enabling them to engage in analytical thinking and systematically solve problems. This skillset is essential for acquiring knowledge and addressing real-world challenges. The researchers were interested in utilising games as a platform to facilitate learning and enhance computational thinking skills. They introduced unplugged coding as a learning medium, wh-ich enabled students to collaborate, analyse solutions, and engage in enjoyable activities. This approach is aimed at promoting learning that develops lifelong abilities. So, the objectives of this study are (i) to compare computational thinking skills before and after using game-based learning activities and (ii) to study students' satisfaction after using game-based learning.

II. LITERATURE REVIEW

A. Computational Thinking Skills

Computational thinking skills encompass a systematic approach to problem-solving, which entails breaking down complex problems into smaller, more manageable parts and devising optimal solutions [10]. The four primary components are [1,11,12]:

- Decomposition refers to the process of dividing a complex problem into smaller, more easily solvable sub-problems.
- Pattern recognition refers to the cognitive ability to discern similarities and repeat patterns in various problem-solving scenarios.
- Abstraction refers to the process of concentrating on the fundamental aspects of a problem while excluding any extraneous or unimportant information.
- Algorithm design refers to the systematic process of formulating a precise sequence of instructions to effectively solve a given problem.

With practice and perseverance, you can develop computational thinking over time. Actively participating in activities that require logical thinking and systematic problem-solving will improve your computational thinking skills.

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B. Learning Activity Design

Designing learning activities is an important step that helps make learning more effective and interesting. Designing interesting learning activities and clearly presenting information will stimulate students' interest and enthusiasm for learning, resulting in a more enjoyable and diverse learning experience. Good learning activities will help create a learning environment for students to truly develop creative and analytical thinking in the classroom [13-14].

Active learning is a process in which students participate fully in building knowledge and understanding. Active learning places a strong emphasis on learning that is enjoyable and engaging, including the use of activities or media to enhance learning, the development of skills for collaborative work and independent problem-solving, and the creation of an engaging learning environment. It is not only the study of knowledge, but also the development of skills and brains so that students can fully grow in every aspect of their lives [15-16]. Learning-based activities serve as a form of active learning, fostering a process of exploration, creation, display, analysis, creation, and exchange of ideas among students. It also promotes an efficient and fun learning process.

C. Game-based Learning

Game-based learning (GBL) is an educational technique that integrates game mechanics and concepts into the process of learning. The goal is to provide an educational experience that is enjoyable, interactive, and captivating [7,17]. GBL's key components include [18]:

- Engaging mechanics: games employ components like challenges, leaderboards, badges, and points to keep players interested and driven to learn more.
- Immersive environments: GBL has the capability to generate virtual environments that allow learners to actively engage and directly experience concepts.
- Immediate feedback: Games frequently offer instantaneous feedback on the learner's performance, allowing them to adapt their strategy and learn from mistakes.
- Problem-solving focus: Many GBL experiences involve solving puzzles, overcoming obstacles, and making strategic decisions, all of which contribute to critical thinking skills.

Overall, game-based learning can be a powerful tool for educators to create a more engaging and effective learning environment. It has the potential to enhance motivation, enhance critical thinking skills, and enhance the overall enjoyment of the learning process for students of all age groups [19-20].

III. Research Methodology

A. Participants

There is a population of 41 students enrolled at the lower secondary school level at Sudinsaharath School, Phra Nakhon Si Ayutthaya Primary Educational Service Area Office 1. These students were studying during the second semester of the 2023 academic year.

B. Instrument

- Game-based learning activity plan: The researcher has developed a design for a learning activity that incorporates game-based learning as a foundation for acquiring knowledge. The plan has four actions, which students will engage until they finish. Snake-and-ladder games are designed to encourage the analysis and breakdown of problems into smaller parts; discovery and search games are exercises that enhance competency in pattern recognition; computer hardware games are exercises that enhance abstract reasoning abilities; and high-speed racing games are exercises that enhance skills in algorithmic design. Three specialists have evaluated this educational activity plan for its quality. The evaluation findings indicate that the quality is excellent, with a mean value of 4.81 and a standard deviation of 0.43.
- Computational Thinking Skills Test : The researcher designed a multiple-choice exam consisting of four alternatives and 15 questions to be administered both before and after the activity. After that, verify the coherence between the question items and the objectives. The examination of the consistency index revealed values ranging from 0.67 to 1.00 for each item, while the analysis of the confidence value gave a result of 0.88.
- Activity satisfaction questionnaire: The researcher designed a questionnaire on satisfaction with game-based learning activities. It is a 5-level rating scale assessment with 12 questions that have been checked for consistency between the question items and the purpose of the assessment, with a consistency index between 0.67 and 1.00.

C. Research Method

The researcher has conducted research using the ADDIE model, as follows:

1) Step of analysis: The researcher conducted an analysis of learning standards and indicators to promote the development of computational thinking skills. Teachers can use unplugged computer science teaching techniques, such as using worksheets or engaging in activities including flashcards, board games, picture sheets, and other materials, to instruct students in logical problem-solving and analysis while also ensuring their enjoyment of the activities.

2) Step of design: The activity design is game-based learning, with activity plans and activity sheets that follow IPST's guidelines for promoting computational thinking skills in four parts: 1) Decomposition uses snake-and-ladder games that focus on answering questions from a given situation by dividing them into sub-sections that make it easier to handle or find answers. 2) Games of discovery and search employ pattern recognition, akin to a sudoku game, to facilitate the observation of relationships. 3) Abstraction uses computer hardware games that focus on answering questions about the functions and features of computer devices. 4) Algorithm design used high-speed racing games that were board-style problem-solving games to find a step-by-step car exit. We will divide the students into four groups for each learning activity.

3) Step of development: The researchers created an activity plan and colorful media using cartoons and computer graphics, developed tests to measure computational thinking skills and satisfaction questionnaires to organize the activity, and then conducted coherence and conviction analyses prior to implementation.

4) Step of Implementation: A game-based learning educational activity was carried out at Sudinsaharath School to improve the computational thinking abilities of 41 lower secondary school students. Execute the activities according to the predetermined plan. The activity can be organised over a span of 24 hours, which amounts to a total of 6 hours. The pupils commence by taking a test to assess their computational thinking abilities. Then engage in four educational activities. Students rotate for 80 minutes within the learning base, then shift to a different learning base until they complete all assigned activities.

5) Step of Evaluation: For comparison, the researchers used a single-sample t-test to look at the scores on the computational thinking skills tests given before and after the activity, and defined the criteria for evaluating satisfaction using an approximate 5-level ratio.

D. Data Collection

- The researchers measured computational thinking skills before and after the activity. It was a computational thinking skills test to find statistical values that consisted of averages and standard deviations, classified before and after the activity, and then compared the computational thinking skills scores using one-sample t-test statistics.
- The researchers conducted a survey to assess the satisfaction of students participating in a game-based learning activity. The researchers used a 5-level evaluation approach to examine statistical values, including average values and standard deviations, to measure overall satisfaction based on specific criteria. The criteria are as Table I.

TABLE I. CRITERIA FOR CONSIDERING THE AVERAGE STUDENT SATISFACTION

Range of average scores	Interpretation of students' satisfaction
4.51-5.00	Highest level
3.51-4.50	Very satisfying
2.51-3.50	Moderate
1.51-2.50	Low level
1.00-1.50	Minimal satisfaction

IV. RESULT

A. The comparison result of computational thinking skills before and after game-based learning activities.

We compared the computational thinking skills before and after engaging in game-based learning activities using the computational thinking skills test, which measures four areas: decomposition, pattern recognition, abstraction, and algorithm design. The test consists of 15 points, which are used to analyze the data and compare the mean with the criteria. Table II summarizes the result.

TABLE II. THE RESULTS OF COMPARING COMPUTATIONAL THINKING SKILLS BEFORE AND AFTER GAME-BASED LEARNING ACTIVITIES

Testing	N	Total score	Mean	t-test	Sig. (1-tailed)
Before activities	41	15	7.07	9.31*	0.000
After activities	41	15	10.17		

*p < .05 t (.05, df 40) t= 1.68

Using game-based learning activities to evaluate students' computational thinking skills before and after activities yielded an average score of 7.07 points and 10.17 points, respectively. The students' computational thinking skills showed a substantial improvement following their participation in game-based learning activities, with statistical significance reported at the 0.05 level. Student scores are indicative of the student's strong academic aptitude. However, there remains a possibility for further advancement. Possible factors that could impact this include adequate preparation, although this may not be exhaustive. The individual demonstrates effective time management and concentration abilities, but there might be a minor decline in their performance as the end approaches. It encompasses the ability to effectively tackle problems of different complexity levels, from simple to moderately complex. However, it can fail to include some of the more challenging ones. Overall, this score indicates a solid basis and promise for future growth.

B. The students' satisfaction after game-based learning activities.

The researcher surveyed students' satisfaction with game-based learning activities using a 12-item satisfaction questionnaire. Table III displays the mean scores and standard deviations of students' satisfaction.

TABLE III. THE RESULTS OF STUDENTS' SATISFACTION WITH GAME-BASED LEARNING ACTIVITIES

Description	Mean	S.D.	Interpretation of students' satisfaction
1. The content is consistent with the purpose of the activity.	4.73	0.55	Highest level
2. The content and activities are appropriate.	4.61	0.70	Highest level
3. The audience easily explains the content.	4.80	0.40	Highest level
4. There is more academic and computational understanding.	4.83	0.38	Highest level
5. This activity can develop more computational thinking skills.	4.68	0.57	Highest level
6. It trains people to help others and work in groups.	4.88	0.33	Highest level
7. It can apply knowledge to everyday life.	4.73	0.55	Highest level
8. The activity is fun.	4.93	0.26	Highest level
9. The duration of the activities is relevant to the content.	4.76	0.54	Highest level
10. The suitability of food and beverages.	4.54	0.74	Highest level
11. The fit of the place.	4.63	0.49	Highest level
12. I would like to do something like this again.	4.85	0.42	Highest level
Overall score	**4.75**	**0.52**	**Highest level**

An analysis of student satisfaction assessment results after the game-based learning activity found that, overall, students were satisfied with this activity at the highest level, with a mean of 4.75 and a standard deviation of 0.52. When considering it, it was found that students who had fun had the highest mean satisfaction (mean = 4.93, S.D. = 0.52).

We can conclude that game-based learning activities can enhance students' computational thinking skills, as students enjoy participating in these activities, leading to their own learning and skill development. Therefore, teachers can apply game-based learning techniques to learning activities, which will result in higher student achievement and skills. Using games as a learning tool is very beneficial, not only for entertaining students but also for stimulating their analytical thinking and computational skills. In addition, participating in game activities with learning content helps to develop students' skills and abilities to go further in their learning and self-improvement with clear results.

Teachers should apply research findings by implementing game-based learning, taking into account factors such as timing, content, media, and location in classroom contexts. While unplugged skills training is appropriate for technology-limited settings, promoting computer programming skills remains critical for future research. Additionally, developing 21st-century skills such as critical thinking, innovation, communication, and collaboration through diverse activities is essential to preparing students for the digital age.

Through games and creative learning activities, students will effectively learn and develop skills such as working with others, problem solving, and creative thinking. This will help increase academic achievement, develop students' abilities to be more efficient, and create a memorable learning experience in the minds of future students. It also helps build a good relationship between students and teachers, which is an important aspect of the learning process.

REFERENCES

[1] V. J. Shute, C., Sun, and J. Asbell-Clarke, "Demystifying computational thinking," Educational research review, vol. 22, pp. 142-158, 2017.

[2] J. M. Wing, "Computational thinking," Communications of the ACM, vol. 49. No. 3, pp. 33-35, 2006.

[3] S. Saenboonsong, "The development of game mobile application to enhance computational thinking skill for primary students under office of Phranakhon Si Ayutthaya educational service area," Journal of Industrial Education, vol. 21. no.1, pp. 56–66, 2022.

[4] C. Selby and J. Woollard, Computational thinking: the developing definition, 2013.

[5] The Institute for the Promotion of Teaching Science and Technology, Using the technology curriculum (Computer Science) Science and technology subject areas, 2017.

[6] D. Barr, J. Harrison, and L. Conery, "Computational thinking: A digital age skill for everyone," Learning & Leading with Technology, vol.38. no.6, pp. 20-23, 2011.

[7] J. L. Plass, B. D. Homer, and C. K. Kinzer, "Foundations of game-based learning," Educational psychologist, vol.50. no.4, pp. 258-283, 2015.

[8] C. Kathinthong, and S. Adipat, "The Development of Vocabulary Learning Using Game Based Learning for Grade 13 Students," Journal of Modern Learning Development, vol.7. no.4, pp. 320–331, 2022.

[9] J. L. Plass, R. E. Mayer, and B. D. Homer, "Handbook of game-based learning," Mit Press, 2020.

[10] J. M. Wing, "Computational thinking and thinking about computing," Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 366. no.1881, pp. 3717-3725, 2008.

[11] C. Angeli, and M. Giannakos, "Computational thinking education: Issues and challenges," Computers in human behavior, vol. 105, p. 106185, 2020.

[12] Y. A. Rodríguez del Rey, et al., "Developing computational thinking with a module of solved problems," Computer Applications in Engineering Education, vol. 29. no. 3, pp. 506-516, 2021.

[13] H. Beetham, An approach to learning activity design, Routledge, 2007.

[14] J. G. Greeno, and Y. Engeström, Learning in activity, 2006.

[15] B. Settles, Active learning literature survey, 2009.

[16] C. Brame, "Active learning," Vanderbilt University Center for Teaching, 2016.

[17] M. Qian, and K. R. Clark, "Game-based Learning and 21st century skills: A review of recent research," Computers in human behavior, vol. 63, pp. 50-58, 2016.

[18] M. Pivec, Guidelines for game-based learning, Pabst Science Publishers, 2004.

[19] M. Hartt, H. Hosseini, and M. Mostafapour, "Game on: Exploring the effectiveness of game-based learning," Planning Practice & Research, vol. 35. no.5, pp. 589-604, 2020.

[20] S. Greipl, K. Moeller, and M. Ninaus, "Potential and limits of game-based learning," International Journal of Technology Enhanced Learning, vol. 12. No. 4, pp. 363-389, 2020.