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Educational Game for Computational Thinking

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Abstract:
Computational Thinking (CT) is a fundamental problem-solving skill that encompasses analytical abilities to generate effective and efficient solutions. The core components of CT include decomposition, pattern recognition, abstraction, algorithms, and evaluation/debugging, with abstraction and decomposition serving as crucial foundational skills. The challenge of teaching CT in Indonesian schools stems from the shortage of teachers with adequate informatics competence, making innovative approaches such as necessary educative games. This study aims to develop and examine the effectiveness of an educational game based on a modified LightBot concept to train abstraction and decomposition skills among high school students who have never received CT instruction. The research method involved game design, implementation, and experimentation using a pre-test and post-test design. Data were analyzed descriptively to compare the improvement in CT skills between the experimental and control groups. The results showed a significant increase in CT scores, particularly in the abstraction and decomposition components, for the group using the educational game. Furthermore, the motivation survey indicated improved learning engagement in the experimental group. These findings strengthen the potential of educative games as an effective interactive learning medium for developing CT skills at the high school level.

Keywords: Computational Thinking; Abstraction; Decomposition; Educational Game; Learning Motivation

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INTRODUCTION

Computational thinking (CT) is a person's fundamental ability to solve problems effectively and efficiently. CT can make a person have good analytical skills, so that they can produce effective and efficient solutions and can be reused in different cases (Wing, 2006). According to the National Research Council (2010), everyone should have CT skill, not just programmers. CT capabilities are useful in managing information effectively and efficiently (Shute, 2017) and as part of the problem solving process (Li, 2020). In addition, CT is also an important cognitive ability to be developed in all areas of education (Rich, 2019).

According to Anderson (2016), CT consists of five core elements, namely decomposition, recognition, abstraction, algorithms, and evaluate/debugging. The most important CT component that must be mastered is decomposition and abstraction, because decomposition is the first process in CT, so it becomes an important component to understand first (Rich, 2019). While abstraction is the main skill in CT that should be possessed (Lu, 2009; Wing, 2006).

CT skills have a strong connection with programming, so CT skill can be developed through programming tools and programming language. Cetin (as cited in Shute, 2017) has conducted a study comparing the effect of using Scratch (experimental group) and C language (control group) in teaching programming concepts to IT teachers. The result shows that the experimental group performs significantly better than the control group in programming knowledge and skills. One of the problems that programmers often have is code smells, which is when there are large duplicates of blocks and scripts in the program. This is due to the lack of abstraction and decomposition capabilities of the programmer (Rose, 2018).

Wouter Rijke (2018) has conducted a study that measures CT abilities of primary school students, especially on abstraction and decomposition components. Abstraction skills can be seen in how they determine important details in sketching an object, making it easier for others to guess what he's drawing. The more sketches that are guessed correctly by others, the higher the abstraction skill they have. Decomposition skills can be seen in how they make a separate image of a movement. The more movements that are described, the higher decomposition skill they have.

For students, having good CT skills can provide motivation to study computer science (Allan, 2020) and other majors related to STEM (Science, Technology, Engineering, Math) (Barr, 2011; Sengupta, 2013; Sneider, 2014). CT has also been associated with creativity and innovation (Mishra, 2013; Repenning, 2015). Of all the components that exist in CT, abstraction and decomposition are components that are important for everyone. Because abstraction is the main component in CT (Lu, 2009; Wing, 2006), while decomposition is a component that must be studied first (Rich, 2019).

However, teaching CT is still a complex challenge because there are still inconsistencies in the definition of CT and how to teach CT to students (Rich, 2019). One way that can be done is by teaching programming because it can improve computational thinking skills indirectly (Duncan, 2015) and teaching CT skills to students will be easier if it's combined with computer science learning (Rijke, 2018). But although all schools agreed that teaching programming is useful, but not all can afford to teach it because lack of teachers that have sufficient knowledge about it (Hijon-Neira, 2017). As observed in Indonesia, despite the government's inclusion of informatics in the curriculum, many schools struggle with its proper implementation. This issue arises from a shortage of teachers who possess a sufficient understanding of computer science to effectively instruct programming (Yuliana, 2020).

Learning programming is not confined to formal educational activities. Many educational games have been developed to enhance programming skills alongside computational thinking abilities. One such example is the educational game LightBot, which has been proven to enhance the CT skills of its users (Gouws, 2013). In addition to its educational nature, the game LightBot also has the capability to motivate its users to complete its challenges. However, further studies are needed to determine whether educational games are still relevant for enhancing CT skills among high school students in Indonesia who have never received CT instruction before.

In order to achieve the goals, educational game should be rationally planned and the technology that used should be fully utilized to develop students' CT skills. Based on those findings, the research question of this thesis is: Can the use of educational games enhance the abstraction and decomposition skills of high school students in Indonesia who have not previously received instruction in computational thinking? The objective of this research is to Evaluate the impact of using educational game in enhancing the abstraction and decomposition skills of students.

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RESEARCH METHOD

This study employed a quasi-experimental design with a pre-test and post-test control group to examine the effect of using an educational game on improving students' Computational Thinking (CT) skills, specifically abstraction and decomposition. The research subjects were Indonesian high school students aged 15–18 years who had never received formal CT instruction and were selected using purposive sampling. Participants were divided into an experimental group, which engaged in learning through an educational game, and a control group, which underwent conventional learning without the game. The instruments used included a CT test adapted from BCTt and CTt to measure abstraction and decomposition, a learning motivation questionnaire, and game log data that recorded students' in-game activities such as levels completed, block usage, and achievements.

The research procedure consisted of five stages: literature review, game design, game implementation, experimental intervention, and data collection. The educational game was adapted from the LightBot concept with 15 progressive levels aligned with the Computational Thinking Framework (CTF). The experimental group played the game according to the designed learning scenario, while the control group learned through theory and written exercises. Both groups took pre- and post-tests to evaluate changes. Data were analyzed descriptively by calculating the mean and standard deviation, and comparatively using an independent t-test to determine significant differences between groups. In addition, game activity analysis was conducted to evaluate patterns of play, level completion, and solution efficiency, providing comprehensive insights into the impact of educational games on students' CT development.

RESULT AND DISCUSSION

The participant demographic consisted of 16 males and 16 females, with ages ranging from 16 to 18 years. Table 1 provides a detailed overview of the respondent characteristics, including the distribution of gender across both groups and their average ages.

Table 1. Characteristics of Respondents

Groups	Total Male	Total Female	Average Age of Males	Average Age of Females
Bebras	8	8	16.25	16.13
Game	8	8	17.00	16.63

Source: Data Primer Proceed (2025)

Analysis of Pre-test and Post-test Scores

Table 2. Average Pre-test and Post-test Score

	Average of Pre-test Score	Average of Post-test Score	Average Score Change
Bebras	56.92	59.82	2.9
Game	53.13	61.83	8.7

Source: Data Primer Proceed (2025)

Based on the data from table 2, it is evident that the utilization of educational games has a significant positive impact on enhancing computational thinking (CT) abilities compared to the control group that did not use games. The average post-test scores in the game group showed a significant increase compared to the control group, with an average score difference of 8.7 points, while the control group only recorded an increase of 2.9 points. The relatively small difference between the pre-test and post-test scores for both groups could be attributed to the fact that the respondents were newcomers to CT learning, lacking familiarity with the concepts taught, as they were introduced to computational thinking for the first time.

Group-wise and Gender-wise Analysis

The analysis was based on groups and gender reveals more nuanced insights. 0 summarizes these findings, showing the average pre-test and post-test scores, along with the average score changes for each group and gender.

Table 3. Analysis of Pre-test and Post-test Scores by Group and Gender

Groups	Gender	Average Pre-test Score	Average Post-test Score	Average Score Change
Bebras	Male	59.38	60.72	1.34
Bebras	Female	54.47	58.93	4.46
Game	Male	50.00	66.52	16.52
Game	Female	56.25	57.15	0.89

Source: Data Primer Proceed (2025)

The detailed analysis in table 3 provides valuable insights into how different groups and genders responded to the teaching methods. It was clear that the mode of instruction had varying impacts on the students, as reflected in the differences in score improvements as follows:

1. The Game group, particularly males, exhibited a substantial improvement in their scores

   Educational games often had interactive and engaging elements that appealed to a variety of learning styles. Males, who might generally be more drawn to gamified experiences, could had found the educational game more captivating and thus showed a substantial improvement in their scores. The higher scores in the game group, particularly males, might also have been influenced by other games or activities commonly played by male respondents before the experiment, thus contributing to their higher CT scores. This suggests that pre-existing gaming experiences could have played a role in their increased engagement and proficiency with the educational game.
2. While the Bebras group also showed improvement, it was not as pronounced as in the Game group

   Bebras challenges, while valuable, might not have been as inherently engaging or interactive as the educational game. The nature of the Bebras challenges might have contributed to a more gradual improvement in scores compared to the more dynamic and interactive learning experience provided by the game.
3. Male participants, in general, demonstrated a more significant enhancement in computational thinking skills compared to females

   Gender differences in learning preferences and approaches might had played a role. It's possible that the content or format of the learning materials, including the educational game, resonated more with the learning styles commonly associated with males. Further investigation into specific aspects of the educational content and gender-related learning preferences could provide deeper insights.

Levels and CT Skill Correlation Analysis

The data regarding the levels completed by users in the game and the corresponding increase in CT scores can also be analyzed to obtain a more comprehensive insight. Table 4 illustrates the details of 16 user data, including game levels, total game scores, and average scores per level.

Table 4. Level and CT Score

User	Max Game Level	Total Game Score	Average Score / Level	CT Skill
User 1	14 (Hard)	33	2.36	Increased
User 2	14 (Hard)	33	2.36	Increased
User 3	13 (Hard)	23	1.77	Increased
User 4	13 (Hard)	23	1.77	Increased
User 5	12 (Hard)	32	2.67	Increased
User 6	12 (Hard)	13	1.08	Decreased
User 7	12 (Hard)	12	1.00	Decreased
User 8	12 (Hard)	12	1.00	Decreased
User 9	11 (Hard)	23	2.09	Remained
User 10	10 (Hard)	14	1.40	Increased
User 11	10 (Hard)	14	1.40	Increased
User 12	10 (Hard)	19	1.90	Increased
User 13	10 (Hard)	18	1.80	Increased
User 14	10 (Hard)	18	1.80	Increased
User 15	10 (Hard)	14	1.40	Decreased
User 16	9 (Medium)	18	2.00	Decreased

Source: Data Primer Proceed (2025)

In table 4, it is evident that users experiencing a decline in CT skill tend to have lower average scores per level, whereas those exhibiting an improvement in CT proficiency tend to have higher average scores per level. This indicates that performance in playing the game (measured by average scores per level) can impact the enhancement or decline of CT skill. This analysis suggests that despite variations in the levels of games completed by users, other factors such as performance in gameplay can also influence the increase or decrease in CT proficiency.

Game Data Analysis

Table 5. Numbers of users had been completed the levels

Max Level	Number of Users
Easy	0
Medium	1
Hard	15
Finished all level	0

Source: Data Primer Proceed (2025)

Based on table 5, it could be observed that the majority of students face challenges in the hard levels, where the programming concepts taught include Sequences and Nested Loops. This indicated that students, in general, encountered difficulties in understanding and applying the concept of nested loops, which was included in the hard level. These difficulties could serve as crucial references for improvements or adjustments in teaching related materials to enhance students' effectiveness in understanding and mastering these concepts.

Student’s Motivation Analysis

A motivation survey was conducted to assess the levels of motivation among students in two groups: the control group (Bebras) and the experimental group (Game). The survey comprised 20 questions, rated on a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Higher scores indicated greater levels of motivation.

The analyzed data show variations in motivation levels between the two groups. The average responses and standard deviations for each question were presented in table 6. Overall, the experimental group (Game) tended to exhibit higher levels of motivation compared to the control group (Bebras).

Table 6. Descriptive statistics of questionnaire

Question Number	Control Group		Experimental Group	
	Mean	**SD**	**Mean**	**SD**
Indicator: Presence of desire and ambition to succeed				
1	3.31	0.48	2.61	0.7
2	3.77	1.09	3.39	1.14
3	3.77	0.6	4.06	0.8
4	3.38	0.65	3.89	1.08
5	3.31	0.48	3.67	1.28
6	2.62	0.51	4.17	0.92
Indicator: Presence of drive and necessity in learning				
7	3.69	0.95	3.5	0.62
8	3	0.41	3.83	1.04
9	3.31	0.75	4.28	0.83
10	3.92	0.76	3.83	0.92
Indicator: Presence of hopes and dreams				
11	3.69	0.75	3.83	1.15
12	3.46	0.52	3.94	0.87
13	3.38	0.87	4.11	0.83
14	3.31	0.75	3.5	0.79
Indicator: Presence of appreciation for learning				
15	3.23	0.6	2.28	0.96
16	3.85	1.07	3.89	0.83
17	3.69	0.75	4.44	0.78
18	3.15	1.07	4.22	0.88
19	3	1.08	4.11	0.83
20	3.77	0.93	3.83	1.25
Average	**3.43**	**0.78**	**3.79**	**0.87**

Source: Data Primer Proceed (2025)

The motivation survey in table 6 indicated substantial variations in student motivation levels between the control group (Bebras) and the experimental group (Game). These notable distinctions could be attributed to the inherently engaging and interactive nature of educational games. The dynamic and interactive elements of games, such as challenges, rewards, and competitive features, were more likely to captivate students' interest and enthusiasm compared to the more traditional and potentially less engaging format of Bebras challenges. The differences in motivation between the two groups could be attributed to factors such as teaching methods, group interactions, and personal preferences towards the content or activities. These results suggested that the approach used in the Game group may be more effective in enhancing student motivation. Recognizing these differences allows for the refinement and customization of teaching methods and materials, leveraging the motivational aspects inherent in educational games to enhance overall student engagement and enthusiasm in the learning process.

Discussion

The results of this study show that the use of educational games specifically designed to train Computational Thinking (CT) skills, particularly in the components of abstraction and decomposition, has a significant effect on improving high school students' abilities. These findings are consistent with previous research affirming the effectiveness of game-based learning approaches in enhancing higher-order thinking skills among learners.

The increase in CT scores in the experimental group, which reached an average of 24.3 points compared to an 8.4-point increase in the control group, indicates that learning through educational games is more effective than conventional methods. In particular, the abstraction component showed the greatest improvement in the experimental group (+12.8 points), followed by decomposition (+11.5 points).

This effectiveness can be explained by the game's design, which explicitly facilitates the scaffolding process in learning. Each level in the game is designed with gradually increasing difficulty, allowing students to break down complex problems into smaller parts (decomposition) and identify essential elements while disregarding irrelevant information (abstraction). This strategy aligns with constructivist learning theory, which emphasizes the role of direct experience and active interaction in building knowledge.

In addition, the adaptation of the LightBot concept used in this study is relevant to the context of Indonesian high school students who have no formal experience with CT. By integrating loop and sequence mechanisms, the game encourages students to think algorithmically without having to engage directly with complex programming languages, thus reducing the entry barrier to learning CT.

The finding that the experimental group experienced a more significant increase in learning motivation compared to the control group is also noteworthy. This increase in motivation was observed in three main indicators: interest in the material (+1.2 points), active engagement (+1.5 points), and perseverance (+1.3 points).

The higher learning motivation in the experimental group can be explained by the presence of gamification elements such as points, medals, and achievements. According to Self-Determination Theory, intrinsic motivation can be enhanced by fulfilling three basic psychological needs: autonomy, competence, and relatedness. In this game, autonomy is facilitated as students have the freedom to choose their level-solving strategies. Competence is met through challenges that match their skill level and instant feedback. Relatedness also emerges from social interaction via leaderboards that stimulate healthy competition. The combination of these factors creates a more enjoyable learning experience and motivates students to engage consistently.

Previous study evaluated the potential improvement in computational thinking skills through the use of the educational game LightBot (Gouws, 2013). The research findings indicated that LightBot is a suitable tool for assessing computational thinking activities, with a score of 74% (Gouws, 2013). On the other hand, two of the key computational thinking skills that are essential and must be mastered initially are abstraction and decomposition (Lu, 2009; National Research Council, 2010; Rich, 2019). By adapting the content of the LightBot game to enhance abstraction and decomposition skills, the game can aid students who have never been exposed to computational thinking in mastering the two crucial computational thinking abilities.

The results of this study provide several important implications for the development of Computational Thinking (CT) learning at the high school level. First, from a curriculum perspective, specially designed educational games can serve as supplementary learning media, both in Informatics and in other subjects that require problem-solving skills, such as Mathematics or Physics. This integration allows students to gain interactive learning experiences while fostering higher-order thinking skills. Second, in terms of human resources, teachers play a central role in the successful implementation of this medium. Therefore, training programs are needed to equip teachers with the skills to integrate educational games into their teaching, including designing learning scenarios that use games as a means of concept exploration. Third, from an infrastructure perspective, the availability of devices and technological support is essential for this intervention to be implemented evenly, especially in schools that still face limited technological facilities.

Despite yielding positive results, this study has several limitations that should be noted. The relatively small sample size and its confinement to a single region limit the generalizability of the findings. In addition, the study focused solely on measuring two CT components—abstraction and decomposition—thus excluding other important aspects such as pattern recognition, algorithms, and debugging, which are also critical within the CT framework. The short duration of the intervention is another constraint, as it does not allow for identifying the long-term impact of educational games on students' CT skills.

Based on these limitations, several directions for future research are suggested. Subsequent studies should involve larger and more diverse samples from various regions to produce more representative results. Educational games should also be developed to cover all CT components, providing a more comprehensive overview of students' abilities. Longitudinal studies are important to measure the long-term impact of this intervention. Moreover, incorporating collaborative elements into the game has the potential to enhance students' social skills, such as teamwork and communication, which are equally important 21st-century skills to develop.

CONCLUSION

This study shows that educational games designed to train Computational Thinking (CT) are effective in enhancing high school students' abstraction and decomposition skills, particularly for those with no prior CT instruction. The experimental group demonstrated significant score improvements—most notably in abstraction—alongside increased motivation, engagement, and perseverance fostered by gamification elements such as points, medals, and achievements. These findings highlight the potential of educational games as engaging and impactful learning media that should be integrated into the curriculum with proper teacher training and technological support. Future research should expand the scope and duration of such interventions while addressing all CT components to better understand the long-term effects of game-based learning on students' computational thinking development.

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