Development of Android-Based Informatics Learning Media to Improve Computational Thinking in High School Students

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Abstract: This study aims to develop an Android-based informatics learning medium, named THINQING, to enhance senior high school students' computational thinking (CT) skills through Bebras informatics problems. The research employed a Research and Development (R&D) method using the Game Development Life Cycle (GDLC) framework, which consists of the stages of initiation, pre-production, production, testing, beta, and release. The participants of this study were 30 tenth-grade students from a senior high school in Garut Regency. Data were collected using the Computational Thinking Scale (CTS), which measures five dimensions of CT: creativity, algorithmic thinking, cooperativity, critical thinking, and problem-solving skills. Data were analyzed using a one-sample t-test by comparing students' CTS scores with a neutral benchmark value. The results reveal a statistically significant improvement in students' computational thinking skills, as indicated by a significance value of p < 0.05. These findings suggest that the THINQING learning medium— particularly its error-based explanatory feedback mechanism—is effective in supporting the development of computational thinking and can serve as an alternative interactive learning tool for fostering 21st-century skills in secondary education.

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Introduction

Computational Thinking (CT) has become a central focus of 21st-century education, with many countries integrating CT into school curricula, particularly within STEM (Science, Technology, Engineering, and Mathematics) disciplines. CT is widely recognized as a fundamental skill that supports critical thinking, problem solving, creativity, and digital literacy. Global studies indicate that effective CT integration enhances students' higher-order thinking skills and fosters interaction between mathematical reasoning and computational reasoning in the learning process (Angeli & Giannakos, 2020; Ye et al., 2023). Consequently, CT is considered an essential competency for preparing students to meet the demands of the digital era (Santos-Meneses & Drugova, 2023).

Programming education has been proven to be highly effective in developing computational thinking skills, as it trains learners to think algorithmically and logically (Lai & Wong, 2022). However, learning programming logic remains challenging for many students. A major difficulty lies in understanding why a program fails and how to correct errors through debugging processes (Coelho et al., 2023). This challenge often hinders students' conceptual understanding and limits the effectiveness of programming instruction, indicating the need for interactive learning media that can support error analysis and logical reasoning.

Previous studies show that the use of interactive learning media, particularly those based on Bebras informatics questions, is effective in improving students' understanding of programming logic and computational problem solving (Vanícek & Simandl, 2023). Bebras tasks emphasize logical reasoning and problem decomposition without relying heavily on syntax, making them suitable for CT development. To ensure the development of engaging and effective learning media, this study adopts a Research and Development (RnD) approach using the Game Development Life Cycle (GDLC) model. The GDLC model comprising initiation, pre-production, production, testing, beta, and release stages has been shown to increase learner engagement and the effectiveness of learning evaluation (Eldo & Najmi, 2025; Rahmadi et al., 2025).

This study aims to develop an Android-based informatics learning media named THINQING, which is designed to support learning through Bebras informatics questions. The novelty of this study lies in the integration of an error-based explanatory feedback mechanism, where learners receive explanations of their mistakes along with suggested solutions for improvement. To evaluate the effectiveness of the learning media quantitatively, this study employs the Computational Thinking Scale (CTS) instrument. The CTS is a standardized measurement tool that assesses five dimensions of computational thinking: Creativity, Algorithmic Thinking, Cooperativity, Critical Thinking, and Problem Solving, allowing for a comprehensive evaluation of students' CT development (Dong et al., 2025; Hikmawan et al., 2025). Accordingly, this study addresses the following research questions: (1) How effective is the THINQING learning media in improving the computational thinking of high school students? and (2) How can the CTS instrument be used to evaluate students' computational thinking abilities quantitatively?

Research Method
Game Design

The research method used in developing learning media for high school students based on Android is based on the Game Development Life Cycle (GDLC) framework. This method comprises six phases of development: initiation, pre-production, production, testing, beta and release (Rahmadi et al., 2025). Figure 1 show the stages of GDLC.
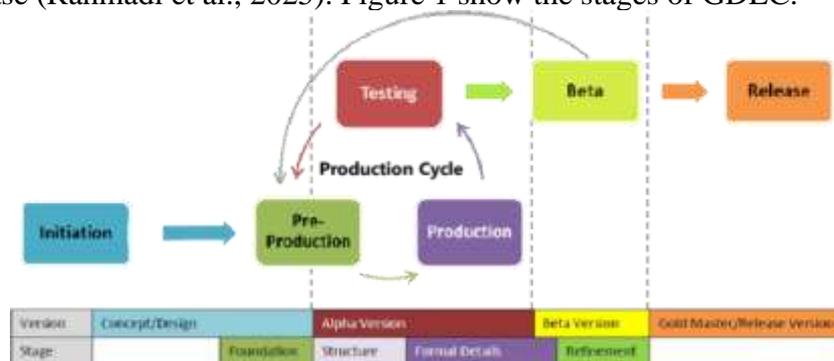

Figure 1. Game Development Life Cycle

The initial stage of developing a game concept, the following steps are taken: setting the topic, identifying the target users, designing the game flow and determining the number of levels required to create an educational game (Oktaviani et al., 2025). The pre-production stage involves several important processes, namely game design, creation of graphic, audio, and video assets, and writing programs to run all game mechanisms. The software used for development is Unity. Table 1 below shows the storyboard.

Table 1. Storyboard

Feature	Function
	Features designed by integrating reading, visual, and auditory elements support various student learning styles (Hooshyar et al., 2021).
	Encouraging students to provide explanations helps them to think systematically, break problems down into smaller parts, recognise important information and organise the steps to finding a solution in a logical way (Ogegbo & Ramnarain, 2022).
	Explaining incorrect answers helps students not only know the wrong answer but also understand the thought process that led to the mistake, so they can correct similar mistakes in the future (Dellantonio & Pastore, 2021; Versteeg et al., 2020).

The testing phase involved black box testing to ensure that each function worked to ensure that each function worked according to the design. Once all function were working properly, beta testing was conducted using a scenario, one-on-one testing with three students to assess the ease of navigation, interface display, and understanding of the instruction in the Android-based quiz application. Improvements have been made to better meet user needs based on interviews and testing with students. After completing the revision stage, the application was released and tested on a class of high school students.

Computational Thinking Scale (CTS)

Computational Thinking Scale (CTS) by Hikmawan et al. (2025) is a measurement instrument designed to assess individuals' computational thinking competencies based on five main theoretical dimensions: Creativity, Algorithmic Thinking, Cooperativity, Critical Thinking, and Problem Solving, which have been tested for validity and reliability. CTS converts aspects of CT into scaled statements (items) that respondent's rate to describe their self-perception of their computational thinking abilities. Table 2 below shows the computational thinking scale instrument.

Table 2. Computational Thinking Scale

No	Items	Indonesian CTS
1	C1	I admire people who are confident in their decision-making abilities.
2	C2	I like people who are honest. I also like people who are impartial.
3	C4	I feel confident in my ability to solve problems in unfamiliar situations.
4	C5	I am confident that I can follow the plan that has been devised to help me resolve my personal issues.
5	C7	I trust my instincts and know what is right or wrong when trying to solve a problem.
6	A2	I think I am particularly interested in computational processes.
7	A3	I would prefer to learn instructions that are created using symbols and computational concepts.
8	A4	I am confident that I am good at finding connections between two things.
9	A5	I can explain how to solve everyday problems computationally.
10	CO2	I think I will achieve better results through collaborative learning, as I will be

		learning alongside my group members.
11	CO3	In collaborative learning, I enjoy solving problems with my friends related to group projects.
12	CO4	I feel like many ideas come to mind when studying with others.
13	CT1	I excel at devising solutions to complex problems.
14	CT2	I enjoy trying to solve complex problems.
15	CT3	I enjoy learning new and challenging things.
16	CT4	I am proud of my ability to think accurately.
17	P3	According to the plan that has been made, I cannot use the solution to solve this problem gradually.
18	P4	I am not accustomed to creating multiple options when solving a problem.
19	P5	I have trouble coming up with my own ideas when solving problems in a group.
20	P6	I feel tired when I must study with my friends while working in a group.

This study involved 30 respondents from State Senior High School 5 Garut in Garut Regency. The respondents consisted of 10th grade students, with 14 male and 16 female respondents who met the criteria of never having used similar media, willing to participate in the entire process, and having access to the necessary devices. To measure computational thinking skills in 30 respondents, a 5-point Likert scale self- assessment scale (Korkmaz et al., 2017).

The data analysis technique used is the one-sample t-test, which is used to determine whether the sample mean differs significantly from the population mean. The null hypothesis (H₀) states that there is no difference in the mean values. Conversely, the alternative hypothesis (H₁) states that there is a difference. If the p-value is less than the significance level, the null hypothesis (H₀) is rejected, and the difference is considered significant (Al-kassab, 2022).

Results and Discussion
Result
The GDLC stages are interconnected to ensure that the game is well structured and functions effectively for end users (Octavia, 2024). The following stages are carried out in the GDLC cycle:

1) The initialization process involved searching and reviewing the literature to identify previous studies that discussed the development or use of learning media for high school students. The learning media was determined after reviewing the literature. The next step was to collect and select relevant Bebras questions to be integrated into the learning media. Integrating Bebras questions and a gamification approach into the learning media effectively improved students' computational thinking skills (Triantafyllou et al., 2024b).

2) Pre-Production, at this stage, the educational content should increase players' interest in learning. Game visualization should be designed in accordance with UI/UX principles (Roedavan et al., 2021)

3) Production, in game development involves several important processes, namely game design, creation of graphic and audio assets, and writing programs to run all game mechanisms with Unity software (Kaźmierczak et al., 2024).

4) The game application underwent alpha testing using the black box method to ensure optimal performance of all its functions. The results showed that all features and

menus were functioning properly in accordance with the development objectives (Pratama & Arisna, 2022).

5) Beta testing was conducted using several test scenarios carried out one-on-one with three students to evaluate the ease of navigation and interface display, as well as the clarity of instructions, on the Android-based quiz application. The students then provided criticism and suggestions for system improvements before the application was released.

6) The final activity involves releasing the game to end users, such as high school students. The goal of this research is to develop THINQING, a tool designed to improve students' computational thinking skills.

Discussion

Descriptive analysis was conducted to describe the distribution of Computational Thinking Scale (CTS) scores obtained by 30 respondents. Table 3 shows the descriptive result.

Table 3. Descriptive Statistics

Statistics	Value
Mean	3.535
Std. Deviation	0.4793
Maximum	4.3
Minimum	2.1

Descriptive analysis results in the table above, the mean value of the CTS score is 3.535. The data's standard deviation is 0.4793. The minimum value is 2.1 and the maximum is 4.3. Before the One Sample t-test was conducted, a data normality test was first performed using Kolmogorov-Smirnov method to ensure that the normality assumption was met.

Table 4. Normality Test

Data	Sig. Value	Description
CTS	0.179	Normally distributed data

The test results concluded that the Kolmogorov-Smirnov value (Sig.) is $0.179 > 0.05$. Therefore, it is assumed that the data follows a normal distribution and that the parametric tests can be performed. Next, a One Sample t-test was conducted using a test value of 3.0 as a comparison. The hypothesis proposed are H_0: the CTS level of respondents is the same as the neutral category, and H_1 : the CTS level is higher than neutral.

Table 5. One Sample t-test

Variable	Sig. (2-tailed)	Description
CTS	0.000	CTS level is higher than neutral

The significance value is $0.000 < 0.05$. This mean H_0 is rejected, and H_1 is accepted. The findings indicate a significant difference in mean CTS values, with being higher than those in the neutral category.

The hypothesis test results concluded that H_1 was accepted, meaning that there was a significant difference between the average CTS scores of respondents and neutral values. These results indicate that THINQING has a positive impact on students' computational thinking skills. These results are in line with previous studies, namely that incorporating game elements motivation, gradual practice, and problem solving (Murniatiningtyas et al., 2024). Emphasizing the combination of text, audio, and video to support learning styles and reinforce computational thinking concepts (Wang et al., 2025). THINQING highlights the feature of explanation by students, encouraging active engagement because students must formulate their own solution, not just choose answer. In addition, there is a feature that

explanation error, which function as diagnostic feedback to correct students thinking patterns (Krouska et al., 2021). This learning resource has been designed to reinforce the elements of CT through a series of functions. Table 6 below outlines the primary functions of the system.

Table 6. Function

Function	Description
	Problem-solving skills are developed by students through the use of Bebras questions, including breaking problems down into smaller parts, identifying important information from the context of the question, recognising relevant patterns, and devising steps for solving the problem (Kang et al., 2023).
	Students solve problems by providing explanations for their answers. Decomposition involves dividing a problem into smaller, more manageable parts. Students can recognize patterns and separate irrelevant information through pattern recognition and abstraction. Algorithms organise the systematic steps for solving problems (Wu et al., 2024).
	When students make mistakes, explanations that highlight how they break down problems, recognise relevant patterns, abstract important information and design solution steps can help them to understand where they went wrong and correct it (de Jong et al., 2024).

These features have had a positive impact, as reflected in improved performance and, most importantly, direct user feedback. Some students provide testimonials, which are listed table 6, after using THINQING.

Table 7. Testimonial

Dimension	Testimonial
Creativity	"*Some questions are difficult to answer, but I began to understand after analysing them and trying them myself.*"
Algorithmic Thinking	"*It was explained that it can be fixed again when the game is restarted.*" "*Input the steps of the answer*"
Cooperativity	"*It's easier to do things together with friends.*" "*Discuss with friends to work together to solve it*"
Critical Thinking	"*Learn to think critically when working on the problems.*" "*Must be able to think critically to answer the questions.*"
Problem Solving	"*Explain why the answer is wrong so that you can learn the correct way.*"

Table 7 presents the results of student's testimonials that describe the strengthening of each CT dimension after activity. Students showed improvement in the Creativity dimension after receiving instructions (Gusti et al., 2024). The Algorithmic Thinking dimension was reflected in the steps taken to solve the problem, following an explanation and opportunities to correct mistakes. In terms of cooperativity, students experienced the benefits of collaborating and discussing tasks with friends (Zhang et al., 2024). Meanwhile, the Critical Thinking dimension was evident through critical thinking skills analyzing problems (Putri Mariana & Dwi Kristanto, 2023). The problem-solving dimension revealed that explaining mistakes helped participants to understand the correct solution (Taufik & Susanti, 2024).

Student feedback reveals how students' computational thinking abilities have developed (Gundersen & Lampropoulos, 2025).

Conclusion

This study concluded that a one-sample t-test revealed the development of an interactive Android-based learning media application with a significance value of 0.000 < 0.05. This indicates that students' CTS scores were significantly higher than those in the neutral category. This means that the use of THINQING media has a positive effect, showing that the CTS scores are significantly higher that the neutral category and improving students, computational thinking skills in five dimensions. Student testimonial also confirm practical improvements that reinforce these dimensions. The answer input and error feedback features were proven to encourage active engagement and reflection, overcoming common obstacles in programming learning such as difficulty understanding code errors. This proves that the developed learning media is effective in facilitating higher order thinking processes and supporting 21st century skills.

Recommendation

Future studies are recommended to involve larger and more diverse samples, applying a longitudinal design with follow-up measurements 1–3 months after testing. Nevertheless, this study provides a reference for the development of similar learning media. Several follow-up recommendations can be proposed for both teachers and future researchers. Teachers are encouraged to implement THINQING media continuously as part of routine classroom activities and formative assessment, utilizing error-based feedback to support student reflection and problem-solving skills. Meanwhile, future researchers can explore broader implementation and longitudinal impacts.

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