EduLine: Journal of Education and Learning Innovation *ISSN: 2775-6173 (online)*
Vol. 3 No. 4 (2023)
https://doi.org/10.35877/454RI.eduline2210

The Analysis of Pre-Service Physics Teachers' Computational Thinking Skills in Designing Computer Simulations of Projectile Motion Using the Scratch Application

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Abstract

Computational Thinking is a skill that plays a significant role in improving students' skills, achievements, and global competitiveness. This research aims to determine the Computational Thinking abilities of preservice physics teachers for each indicator by creating a simulation using the Scratch application. This research is a descriptive qualitative study. The respondents involved in the research were 10 pre-service physics teachers at Khairun University. The respondents are students who have taken Computer Programming courses. The saturated sampling technique was used to determine the respondents. The data collection technique for this research is a test. The instrument used is a simple project to simulate projectile motion. The results of this research show that all students were able to complete the abstraction and generalization components perfectly. Furthermore, in the decomposition and algorithmic thinking components, two students made incorrect commands in the Scratch application. However, after the interview, it was revealed that the error was not due to their lack of understanding of physics concepts, but rather due to the limitations of mathematical operations in the Scratch application. Importantly, several students explained that most of the Computational Thinking components had already been developed through their habit of solving physics phenomena cases. Therefore, it can also be concluded that Computational Thinking can train students to solve physics problems effectively.

Keywords: Computational thinking, Scratch, Physics education.

1. Introduction

The 21st century revolution has an impact on all aspects of life, including education. The education world has a major role in improving student skills so that they can achieve, compete globally, and play an important role in it. One skill that can support this is Computational Thinking (Azizah, et al, 2022).

Computational Thinking was first proposed in 1980 by Seymour Papert, an educator and researcher in the field of computer science from the Massachusetts Institute of Technology (MIT). Papert conceived the concept of "logo programming language", which allows children to learn mathematical concepts through computer programming (Christi and Rajiman, 2023). Later in 2006, Wing also helped to popularize Computational Thinking. According to Wing, Computational Thinking is a set of intellectual and thinking skills that describe how humans interact and learn with computer languages (Astuti, et.al., 2023).

In other studies, Maharani et.al (2019a; 2019b: 2020) stated that Computational Thinking is an important skill for students, because in the problem-solving process it focuses not only on the outcome of the problem but more on how to solve it. Then according to Citta, et al., (2019), Computational Thinking is a series of abstract mental activities in the form of reasoning processes such as abstraction, decomposition, pattern drawing, identification of patterns, algorithmic thinking, automation, modelling, simulation, evaluation, experimentation. Zahid (2020) also said that in the PISA framework, Computational Thinking can function in the problem-solving process, when formulating problems, and when doing mathematical reasoning. Based on previous research, Computational Thinking is very important, because it can help someone develop critical thinking, creative, and analytical skills in solving complex problems, both in computational context and in everyday life.

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Computational Thinking applies a wide range of strategies in solving complex problems. Algorithmic thinking, decomposition, abstraction, and generalization are the foundation of Computational Thinking that can guide students in solving a complex problem (Kawuri, et.al., 2019). The following are the indicators of Computational Thinking: (1) Abstraction or pattern recognition is the ability to identify patterns or information used in solving problems, (2) Algorithmic thinking is the ability to design step-by-step actions or the flow of solving a problem, (3) Decomposition is the skill of solving a complex problem in a simple form so that it is easy to understand and solve, (4) Generalization is the ability to determine a general solution to be applied in solving different problems (Suprihatiningsih, 2020).

Furthermore, in another study by Widiningrum, et.al. (2021), a meta-analysis of the Scratch media on the Computational Thinking skills of high school students in physics learning was conducted. The results of the study showed that Scratch can improve students' Computational Thinking skills because the media is designed to develop creativity when designing animations and simulations, the ability to think systematically, collaboratively, and can realize algorithms so that it can apply logical thinking patterns that can make simple concepts complex in physics learning. Furthermore, in the study by Ibrohim (2022), Scratch in learning was proven to significantly improve students' Computational Thinking skills. Based on these studies, it is known that the Scratch media is one of the effective media to improve Computational Thinking skills.

Based on previous studies, it is explained that Computational Thinking becomes a basic thinking ability for students and provides a new way of thinking that can be used to solve problems. In physics subjects, almost all of the material can be packaged and presented in problem-based learning. Even the results of a study by Maunino, et.al (2023) also explain that problem-solving can improve the understanding of physics concepts. This is also in line with the study by Lestari and Jatmiko (2023) that problem-based learning can make students remember physics concepts longer in the long term and is effective for solving authentic problems. Based on these studies, it can be known that Computational Thinking can become an important component in physics learning because it can support the ability to solve physics problems.

Further research on Computational Thinking is needed, especially since previous studies have never examined the Computational Thinking skills of pre-service physics teachers, especially in the region of North Maluku. In the study by Ifriliya, et.al (2022) titled "*Potensi Implementasi Computational Thinking pada Pembelajaran Fisika*", the results showed that the development of Computational Thinking skills is very relevant to the objectives of physics learning in schools, one of which is to develop the ability to reason in inductive and deductive analytical thinking. Therefore, the author intends to examine the Computational Thinking skills of pre-service physics teachers in the creation of projectile motion simulations using the Scratch application.

2. Research Methods

The type of research is descriptive qualitative. The respondents involved in the study were 10 pre-service physics teachers from the Physics Education Study Program, Khairun University. The characteristics of the respondents were pre-service physics teachers who had taken the Computer Programming course. The technique used to determine the respondents was the saturation sampling technique. The saturation sampling technique is a sampling technique in which all members of the population are made samples (Sugiyono, 2019). This technique was chosen because it allows for the observation of all existing samples, namely 10 pre-service physics teachers who are taking the Computer Programming course. The data collection techniques used in this study were data triangulation by conducting observation, interviews, and documentation. The instrument used was the Scratch 3.29.1 application.

There are three stages in this study. First, provide a practical exam to create a projectile motion simulation using the Scratch 3.29.1 application. The projectile motion simulation that was created was projectile motion with an elevation angle that can be adjusted $0 < \theta < 90°$, initial height of 0 m and the influence of the earth's acceleration of gravity of 9.8 m/s2. Objects and backgrounds were not set so that respondents could choose according to their own creativity.

Stage two, analyzing the components of Computational Thinking that appear in the results of the parabolic motion simulation created by the respondents. The components of Computational Thinking in this study can be seen in the table 1.

Table 1. Computational Thinking Components

Computational Thinking Components	Activities
Abstraction	Pre-service physics teachers can decide whether to use or reject an object, which can be interpreted to separate important information from unnecessary information
Algorithmic Thinking	The ability to design step-by-step operations/actions on how to solve a problem
Decomposition	The ability to break down a complex problem into simpler problems that are easier to understand and solve
Generalization	The ability to formulate a solution in a general form so that it can be applied to different problems, which can be interpreted as the use of variables in solving solutions

(Yuntawati et.al., 2021)

The third stage, triangulating the data to confirm the results of the analysis by conducting interviews. The interview guide used was a structured and open format. A structured interview is an interview using the same questions for all respondents. These questions have been prepared beforehand and cannot be changed during the interview. Thus, structured interviews allow researchers to collect data that can be easily compared. An open interview is an interview where the direction of the questions gives the informant the opportunity to argue and is not limited to just answering yes or no. Some aspects of the interview questions are as follows: (1) What variables are needed to simulate parabolic motion? (2) Explain what sequence of commands you need to simulate the motion of a parabola? (3) How do you determine the position of the x-axis and the position of the y-axis with the previous variables to form a parabolic trajectory? (4) If you were to create another motion simulation, such as Constant Acceleration, explain the similarities and differences in the steps in preparing it?

3. Results and Discussion

The first stage, all 10 pre-service physics teachers were asked to create a parabolic motion simulation individually. The implementation location was at the Computer Laboratory, Faculty of Teacher Training and Education, Khairun University. In this stage, pre-service physics teachers were given 1 hour from turning on the computer to saving the results of their simulations.

The second stage, analysis of the Computational Thinking components. After the work results of each student were obtained, observations and analyses were carried out. The first observation was on the Abstraction component. In this component, observations were made on the students' ability to decide whether an object should be used or rejected, which can be interpreted to separate important information from information that is not used. In the creation of a parabolic motion simulation, the most important thing is to make a decision about which variables will be used. The variables used include elevation angle, acceleration due to gravity, time, initial velocity, initial velocity on the x-axis, initial velocity on the y-axis, initial position on the x-axis, final position on the x-axis, initial position on the y-axis, and final position on the y-axis.

In the abstraction component, respondents determined all the variables in the equations used to create a parabolic motion simulation. At this stage, it was found that all 10 pre-service physics teachers had completely and correctly determined the variables used in the creation of the parabolic motion simulation. The following Figure 1 shows the variables that have been input into the Scratch application.

In solving problems in the field of physics, both in the form of test questions and in everyday life, the first thing that is usually done is to determine the variables, so that determining the variables is a basic thing that is usually done by pre-service physics teachers. Thus, the results obtained are also maximal, namely that all respondents can determine the variables correctly and completely. This is in line with research (Adam, 2017) that the ability to identify variables is one of the important things because with this ability, you can better understand and understand physics problems.

The second observation is on the algorithmic thinking component. algorithmic thinking is the ability to design step-by-step operations/ actions on how to solve a problem. In this component, respondents were asked to compile the commands that are needed to create a parabolic motion simulation.

The commands that are required to create a parabolic motion simulation are located in the following menus: 1) Pen, this command includes setting the dotted line for the parabolic trajectory so that the shape of the trajectory is recorded; 2) Variables, this command includes setting the variables that have been added previously to be given a value or substituted into an equation that contains other variables; 3) Motion, this command includes setting the initial and final positions of the object, which can be given a value directly or filled in with a variable whose value then depends on the calculation results of the variables entered; 4) Events, this command includes commands to start running the code with a click of the flag and also includes commands to repeat the calculation until a certain desired condition is reached; 5) Sensing, this command is included in the repetition command to set the end limit of the repetition.

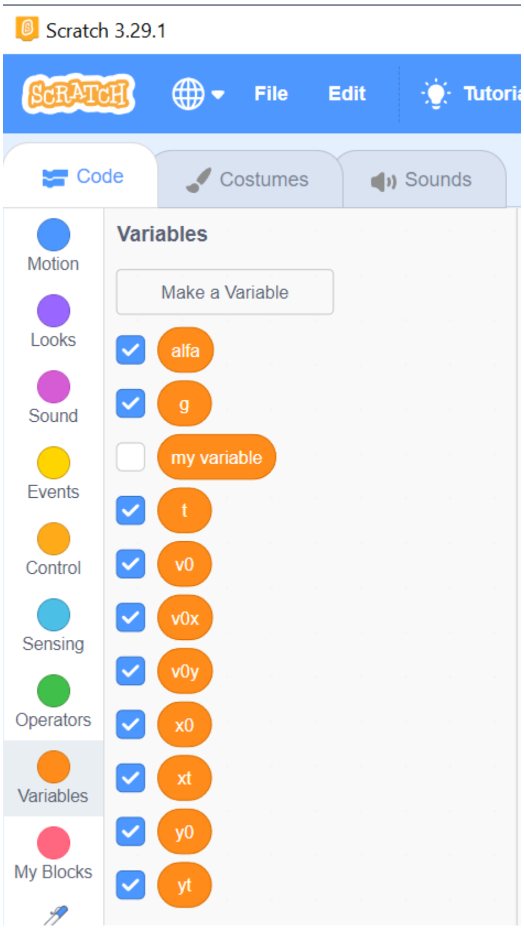

Figure 1. Physics variables in the parabolic motion equation that have been input into the Scratch application

In the second observation, it was found that 8 of 10 pre-service physics teachers correctly and sequentially compiled the commands so that the object moved in a parabolic trajectory and stopped precisely at the bottom. The other 2 pre-service physics teachers did not provide the sensing – touching edge command, so the result was that the object moved in a parabolic trajectory but when it reached the bottom, the object continued to move in a straight line, which should have stopped. The following are Figures of the code and the results of the parabolic motion and its trajectory.

The algorithmic thinking is a higher stage after the determination of variables. In the algorithmic thinking, not all pre-service physics teachers are able to compile commands in a sequential and correct manner. This is in line with research (Mufidah, 2018) that someone who is able to think algorithmically has high mathematical logical intelligence and mathematical pattern intelligence.

The third observation is on the decomposition component. Decomposition is the ability to break down a complex problem into simpler problems that are easier to understand and solve. In the creation of a parabolic motion simulation, the initial position of the object is input using the variables x_0 (initial position on the x-axis) and y_0 (initial position on the y-axis). Then the final position of the object is input using the variables x_t (final position on the x-axis) and the variable y_t (final position on the y-axis). The variables x_0, y_0, x_t, and y_t cannot be directly given a certain value but are the result of simplification of the parabolic motion equation. In this component, the researcher observed how pre-service physics teachers made the correct parabolic motion equation so that when the variables are input, they can form a perfect parabolic motion trajectory.

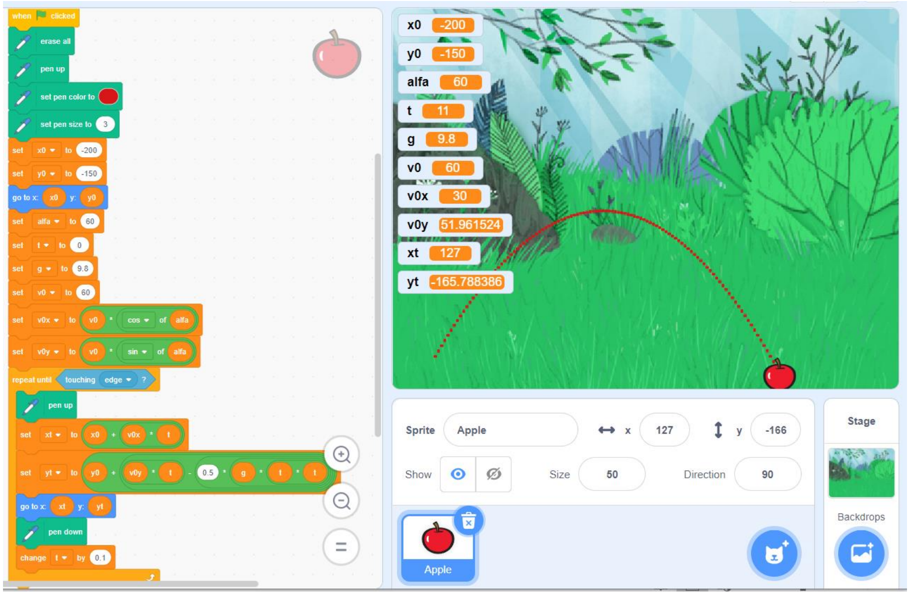

Figure 2. Result of the simulation after adding the touching edge command to the repeat command.

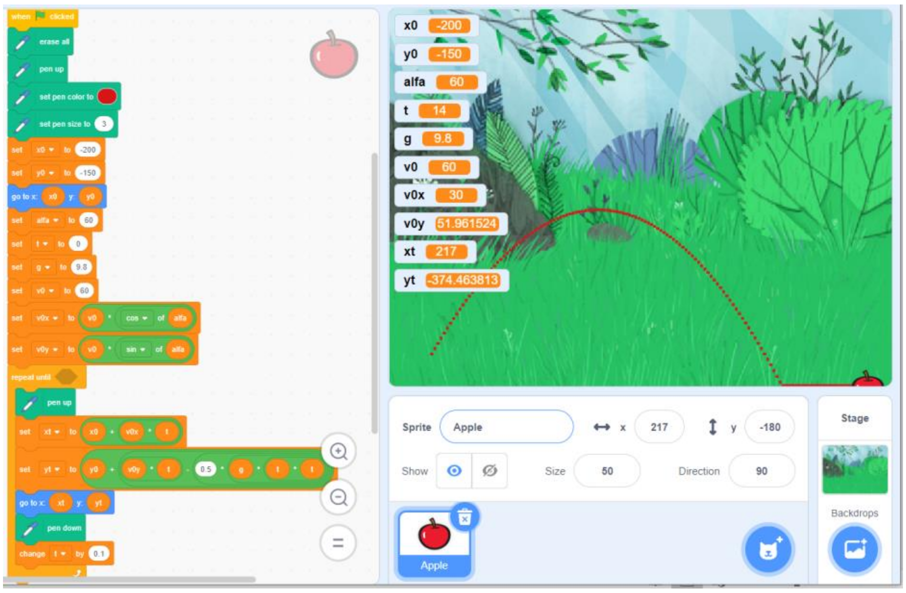

Figure 3. Result of the simulation that is not limited by repetition

In the third observation, it was found that 8 of 10 pre-service physics teachers correctly wrote the parabolic motion equation into the code, resulting in a parabolic motion with a perfect trajectory. The other 2 pre-service physics teachers had errors in their motion equation, so when the simulation was run it became a straight line. The following Figures show the trajectories of the correct and incorrect equations.

From the two figures above, it can be seen that the difference is in the variable yt. In Figure 4, the equation is $y_t = y_0 + v_{0y}.t - \frac{1}{2}.g.t^2$, while in Figure 5 the equation is $y_t = y_0 + v_{0y}.t - \frac{1}{2}.g.t.2$. In image 4, there is a quadratic term for t, so the trajectory is parabolic, while in image 5 there is no quadratic term for t, so the line formed will be a straight line.

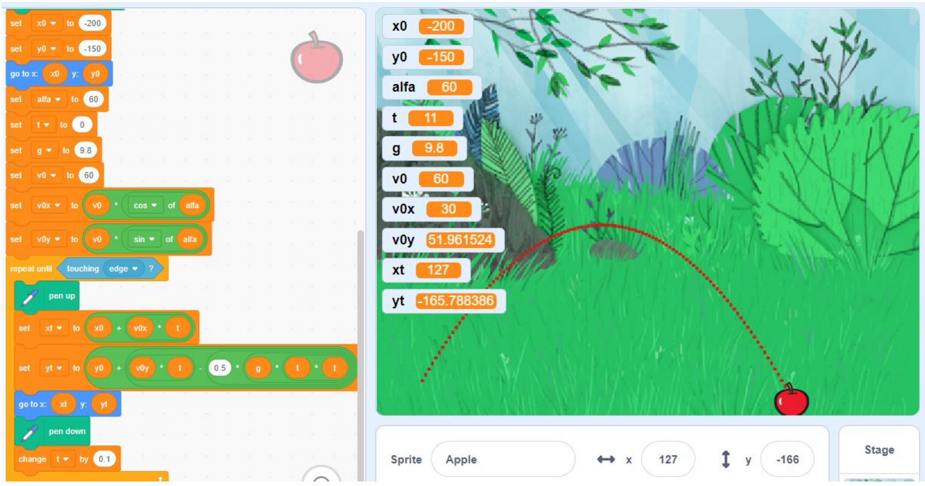

Figure 4. Simulation result with a correct equation

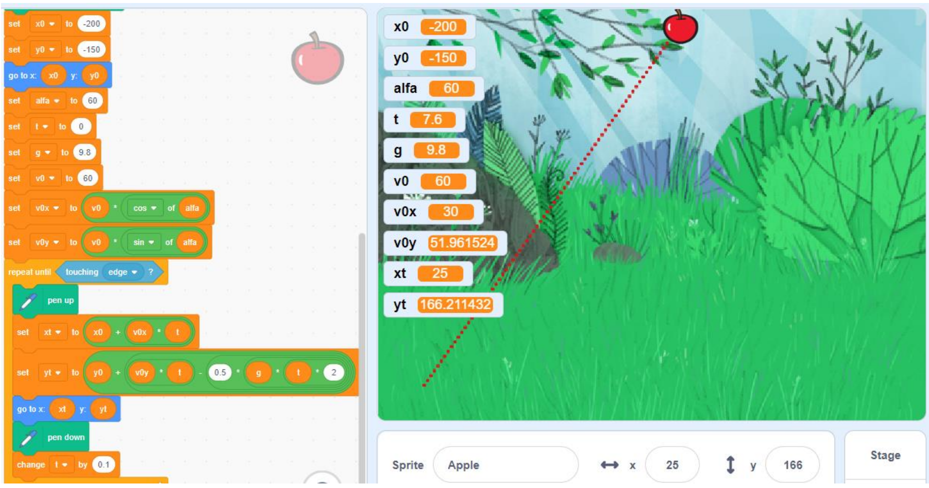

Figure 5. Simulation result with an incorrect equation

In the decomposition component, not all respondents were able to simplify the equation to one variable, but the majority of the total respondents were able to simplify it correctly. This is in line with the research of Asiyah et al. (2021), which states that the design of problem presentation displayed in the form of images and accompanied by information makes the problem simple enough to find a solution. It can be seen that the Scratch application interface is presented in the form of images, so this is in line with the opinion of Asiyah et al.

The fourth observation on the generalization component was taken in the interview session. Generalization is the ability to formulate a solution into a general form so that it can be applied to different problems, can be interpreted as the use of variables in solving solutions. In this component, the researcher wanted to know how far the understanding of pre-service physics teachers towards the commands that they have compiled so that they can be implemented in different motion simulations. If pre-service physics teachers can master the basic concepts of Computational Thinking, pre-service physics teachers will not only be able to complete the code compilation on other motion simulations, but more importantly, pre-service physics teachers will be able to implement the concept in problem solving in everyday life. This is in line with the opinion of Silva, et.al that computational thinking not only helps us acquire skills related to computers, but can also improve our ability to solve problems in other domains, including real phenomena in everyday life (Silva, et.al., 2021). This opinion is also supported by Scherer that Computational Thinking can improve our problem-solving skills (Scherer, et.al., 2019).

The third stage is data triangulation. This stage is carried out to confirm the results of the analysis by conducting interviews. The triangulation technique used is observation, interview, and documentation. Documentation is obtained from the data of the work of pre-service physics teachers, then observation and analysis are carried out on the work of pre-service physics teachers and finally an interview is conducted to confirm the results of the analysis.

On question (1) List the variables that are needed to create a parabolic motion simulation? All pre-service physics teachers can answer correctly. This is also in line with the results of the documentation that all pre-service physics teachers entered the variables correctly in the application.

Question (2) Explain the sequence of commands that you need to create a parabolic motion simulation? On this question, 7 pre-service physics teachers also managed to mention the sequence of commands starting from the Pen settings, entering Variables, giving Motion commands, Event commands, to Sensing commands. The next 3 pre-service physics teachers did not mention the Sensing-touching edge command. This is also in line with the results of the observation where 2 simulations of pre-service physics teachers were not given the Sensing-touching edge command, while 1 pre-service physics teachers in their simulation displayed the Sensing-touching edge command but forgot to mention the command during the interview.

Question (3) How do you determine the position of the x-axis and the position of the y-axis with the previous variables to form a parabolic trajectory? On this question, all pre-service physics teachers can answer correctly and even write the equation correctly. This is not in line with the results of the documentation and analysis because there are 2 pre-service physics teachers who made mistakes in entering the equation. After further interviews, it turned out that the 2 pre-service physics teachers knew the equation correctly but were confused when writing the quadratic equation in the Scratch application. In the Scratch application, there are only 4 operators available, namely +, -, *, and /, so if you want to write t^2, you have to write t*t.

Question (4) If you were to make a simulation of another motion, such as Uniformly Accelerated Motion (UAM). Explain the equation and the differences in the steps in its compilation? On this question, all pre-service physics teachers can answer correctly, namely the equation is contained in the commands entered, while the differences are in the variables entered and the physical equations written.

Computational Thinking involves problem solving with a logical and systematic mindset that involves algorithms, data representation, problem decomposition, and the use of abstraction. Computational Thinking is important because it can help someone develop the ability to think creatively and analytically in finding solutions to complex problems, both in the field of computing and real-world events in everyday life. This is in line with (Nagai, et.al., 2019) that Computational Thinking is considered related to creative thinking because computing is a creative activity, which allows someone to change from a technology consumer to a producer. The importance of Computational Thinking is also realized as the development of creativity in education (Fishelson et al., 2021). Computational Thinking can help in developing skills, designing, and implementing effective and efficient solutions by utilizing technology. With Computational Thinking, someone can also develop the skills to identify errors or weaknesses in a solution and fix them quickly (Christi & Rajiman, 2023).

4. Conclusion

The results of this study showed that all pre-service physics teachers were able to complete the abstraction and generalization components perfectly. In the decomposition and algorithm components, two pre-service physics teachers each made mistakes in creating commands in the Scratch application. However, after interviews, it was revealed that these mistakes were not due to their lack of understanding of physics concepts, but rather due to the limitations of mathematical operations in the Scratch application. The important point from the results of this study is that several pre-service physics teachers explained that most of the Computational Thinking components had been built from their habits when solving cases of physical phenomena. Thus, it can also be concluded that Computational Thinking can train pre-service physics teachers to solve physics problems.

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