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Computational Thinking Skills to Solve Kinematics Problems at High Cognitive Level Cases

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Abstract: Problems of kinematics of rectilinear motion in high-level cognitive level problems often display complexity in their solutions. This research aims to describe the use of computational thinking (CT) methods in helping students solve linear motion kinematics problems designed at a high cognitive level (analysis, evaluation, and creation). This research uses a descriptive quantitative method by using skills observation sheets and analysis of performance results as data collection instruments. The sample was 14 students from the Natural Sciences Tadris study program in introductory physics courses. This research's data analysis technique uses an interpretation of student performance results in solving linear motion kinematics questions at a high cognitive level using the performance stages of the CT method. Significant findings show that the average student cannot solve cases at a high cognitive level using CT skills. Students can only complete and pass the stages of computational thinking skills in the temporary decomposition and abstraction phases but have difficulties in the visualization and design stages at the analysis, evaluation, and creation levels.

Keywords: Computational thinking; High orde thinking; Kinematics lesson

Introduction

Several times I taught kinematics, I found confirmation from students who said they understood the material I explained. When I checked their memory mastery and understanding of concepts, they mastered them quite well. Unfortunately, when I conducted a knowledge test at a high cognitive level in the form of casuistic problems, only 35% of students had good scores. A similar thing was also explained (Setyarini et al., 2021; Sutarno et al., 2021) who stated that several students had difficulty applying their understanding in solving physics questions. It is also explained by (Docktor et al., 2015; Kaluza, 2018), that problem-solving skills in physics lessons are the output of actual learning because this section proves the quality of students' understanding and analytical power. Many students claim to understand the teacher's explanation (Adams & Wieman, 2015) but make many mistakes when tested to solve problems (Lin & Singh, 2015). This is caused by low articulation of the meaning of the case, minimal understanding of concepts, and low analytical skills (Badriev & Banderov, 2014).

It is acknowledged that each student's skills in carrying out case analysis tend to differ depending on the duration and interest of each student (Argaw et al., 2017; Gröber et al., 2014). However, students at the same grade level usually have the same standard of knowledge (Zhao et al., 2020) . In its implementation, several facts show that students have difficulty understanding the direction of the problem in the cases given by the teacher (Yusuf & Widyaningsih, 2019). This is suspected to be because their knowledge of material concepts related to the case is still minimal, and their ability to analyze the direction and intent of the case is also still low (Burko, 2016). Another factor that adds complexity is presenting kinematics problems using language that requires in-depth analysis and interpretation (Adams & Wieman, 2015; Docktor et al., 2015). The slowness of students understanding the meaning of kinematics cases is greatly influenced by

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students' understanding of the concepts of the material presented (Kanderakis, 2016).

Another fact was found that students needed to be more aware of the language of the questions and several parameters listed in them, which often led to misconceptions (Mao & Sen, 2018). This is caused by weak integrated problem-analysis and manipulation skills (Diansah et al., 2021; Koh et al., 2014) . In this case, a unique method is needed to decompose several variables into small components and simultaneously integrate the concepts and case meanings into a significant issue. After reviewing several suitable ways (Cheng & Zhang, 2021; Sartika & Humairah, 2018), the computational thinking method met the criteria to be tested to solve this problem.

Computational thinking (CT) is a thinking skill that adopts the workings of a computer program, which duplicates human thinking (Angeli & Giannakos, 2020; Lee et al., 2011; Nouri et al., 2020). This duplicate content only refers to a computer performance system that can solve a problem by partitioning it by sorting it one by one and coding individually (Tang et al., 2020; Tikva & Tambouris, 2021). Then, the code is re-integrated to complete a big issue, so what then applies is a general code that is used for that widespread problem (Yadav et al., 2016). Next, a patented pattern or formula can solve other problems with the same or similar problem direction as the previous problem.

Computational Thinking has existed since the 1950s (Tedre & Denning, 2021). However, this terminology became more widely known in 2006 when (Tedre & Denning, 2021) explained it in his article. He revealed that Computational Thinking is a new problem-solving method using extensive computer science techniques. This concept is strengthened by Denning (2009) by formulating how CT works, namely using structured thinking and algorithmic thinking to produce output that matches the input provided. On the other hand, computational thinking is the development of knowledge in designing computational solutions to solve problems that involve algorithmic thinking and coding (Angeli & Giannakos, 2020). More specifically (Voskoglou & Buckley, 2012) describe the various stages of CT, including problem decomposition (breaking down complex problems into simpler ones), algorithm development (step-by-step solution to problems), and abstraction. The same thing was also conveyed by (Cansu & Cansu, 2019) who stated that the CT component involves problem-solving, system design, and understanding human behavior by describing basic computer science concepts.

This is similar to the general definition of computer rational thinking, which emphasizes several procedures for solving problems or cases by sorting each condition and variable in the case and then identifying them in the partition (Chevalier et al., 2020; Hershkovitz et al., 2019). This partition was followed by an in-depth interpretation process to ensure the correctness and accuracy of the analysis results (Shute et al., 2017). Partial case concepts are combined and integrated with other meanings to form a complete meaning (Bers et al., 2014). Next, solution design is carried out, as well as the formation of a method prototype so that it can be duplicated as a tool to solve the solution to the next problem that is similar or the same as the case example that has been solved (Gretter & Yadav, 2016). This problem-solving method is used in physics learning to unravel several complex problems for students to understand so that they can be solved quickly, especially in cases at a high cognitive level, namely at the analysis, evaluation, and creation stages.

Thus, Computational thinking skills consist of four levels of basic techniques arranged systematically, namely ability 1). decomposition is the process of breaking down a problem into smaller parts; 2). Abstraction is the process of focusing on the most critical information and parts; 3). Visualization, namely filtering information to find similar problems, and 4). Design is the testing stage to ensure that the solution remains fit for purpose.

It turns out that computational thinking can be adopted as a problem-solving method in learning, such as abstraction and decomposition (Lye & Koh, 2014). CT as a learning method was also expressed (Hsu et al., 2018), stating that CT can be combined with project- and problem-based learning methods. In addition, (Lye & Koh, 2014) state that CT can be applied simultaneously with cooperative learning methods and game-based understanding, which emphasizes problem-solving activities. CT as a learning method is not only used in Indonesia; Malaysia has also introduced computational thinking skills as part of curriculum integration updates to meet global trends in 21st-century education, focusing on empowering digital literacy (Ung et al., 2022). However, initial investigations revealed that teachers needed to understand computational thinking skills in general, so they needed more confidence to use them.

In physics learning, all activities involve cognitive elements from beginning to end (Kao et al., 2017). This process is the center of attention of practitioners and researchers to maximize the transfer and acquisition of knowledge from source to recipient (Damayanti et al., 2020; Velásquez-Rojas & Laguna, 2021) . Knowledge has its difficulty level according to the density of its analytical structure. Learning physics involves cognitive effort in understanding and applying that understanding in the form of valuable creativity. The hierarchical cognitive process space, as expressed by

(Grebin et al., 2020) states that there are six levels, but recently, this idea was updated by Anderson and Kratwol (Chiou & Anderson, 2010). This cognitive level specification is divided into low-order thinking skills, namely the remembering, understanding, and applying stages, and high-order thinking skills in analysis, evaluation, and creation (Lusiana & Andari, 2020). To solve problems at the HOTS level, specific methods are needed to resolve a case or issue so that the issue is fixed effectively and efficiently.

Several researchers have researched computational thinking in learning, such as research Yuntawati et al. (2021) which revealed that computational thinking is combined with cooperative learning to help students solve mathematics problems effectively. Research Supiarmo et al. (2021) found that scaffolding can help and improve students' computational thinking processes by providing questions, instructions, reminders, directions, or encouragement, optimally activating students' computational thinking. Research from Supiarmo et al. (2021) states that students' computational thinking abilities are not significantly different because they are limited to the pattern recognition stage. Meanwhile, the applied problem-solving step is still less coherent because abstraction and abstraction have not been carried out think algorithms in solving problems. Another case was found by Lestari et al. (2023) who explained in more detail by first identifying students' computational abilities and then conducting a weakness analysis. In his conclusion, he explained that students in the outstanding computational thinking category were able to meet all the CT indicators, students in the excellent indicator were able to meet all the hands but were less than perfect in the abstract thinking indicator, students in the fair category were able to meet the decomposition and pattern recognition indicators. Still, they needed to focus more on pattern recognition and abstraction indicators, while students in the low categories cannot fulfill all the existing hands. Meanwhile, community service activities (Apriani et al., 2021), which train teachers to apply CT in learning, reveal that most teachers want to use computational thinking.

Meanwhile, research at a high level of cognitive level has also been widely carried out, such as research (Kirana & Kusairi, 2019) which explains that students have critical thinking skills in the low category, which causes the average score to only increase by a few points from the previous score. In this case, students have difficulty determining instantaneous velocity from the position-time graph and displacement from the velocity-time graph. Research from Novitasari et al. (2021) compares visualizer and verbalizer students using high-level cognitive skills. The high-level thinking abilities of visualizer students at the analyzing stage are considered sufficient, where they can only identify the information in the question but still need to state it completely. In this learning style, students must be more able to judge, deny, and give reasons. Students are also quite capable of designing problem solutions. However, visualizing from verbal form to visual form is challenging. Meanwhile, at the analyzing stage, verbalizer students are classified as particularly good and able to analyze and state information thoroughly. Also, at the evaluating step, it is classified as deficient; students need to be able to assess, deny, and give reasons. At the creation stage, it is considered good; verbalizer students can design solutions and visualize the shape of objects from verbal to visual. To solve this problem, research Mairani et al. (2018) offers a solution by using problem-based learning models in learning because there is a significant influence of using problem-based learning models on students' high-level cognitive learning outcomes.

Based on the description above, from the definition of several research results, no study has been found that explains the use of computational thinking in physics learning, specifically in discussing the kinematics of rectilinear motion. There is only research in mathematics (Gadanidis, 2017; Pei et al., 2018; Rodríguez-Martínez et al., 2020) describing using computational thinking to solve mathematical problems. However, some of these studies have not been able to relate computational thinking methods to the case of kinematics at a high cognitive level. So, this research is considered *a* pioneer that first revealed the use of computational thinking in solving kinematics problems at a high level of cognitive skills. This is needed to answer students' difficulties understanding, analyzing, and manipulating various languages and meanings. So, this research is intended to provide a preferred reference for physics education practitioners and researchers to focus on students' understanding in solving factual cases in everyday life using practical and efficient methods, especially on difficult questions according to cognitive level.

Method

This research uses a phenomenological study using descriptive quantitative data comparisons to describe students' abilities in using computational thinking skills to solve problems at a high cognitive level. The cognitive level refers to the description presented by (Ahmad et al., 2018; Walid et al., 2019), namely high-order thinking skills based on the ability to analyze, evaluate, and create. This research material focuses on the kinematics of straight motion and motion in two dimensions. The objects of this research were 14 students from the Science

Education study program who were taught introductory physics courses.

The data collection techniques were learning activity observation sheets and student performance portfolio analysis sheets. The performance observation in question is observing student activities in solving problems both in the process and afterward. CT skills in the problem-solving process were observed through student performance stages. Student performance sheet analysis assesses participants text performance results, including performance stages according to computational thinking skills. The data analysis used in this research uses descriptive quantitative analysis, which describes a series of numbers as a representation of student's abilities in solving problems using CT, as well as a descriptive analysis of the results of observations of the learning process that occurs in the classroom.

This research began with preparation and learning planning, where the researcher prepared questions and problems on the kinematics of rectilinear motion at each high cognitive level. Two questions represent each cognitive level. So, the total number of items consists of 6 case questions. In the next stage, the researcher taught students material on the kinematics of rectilinear motion, starting from position and velocity, uniform rectilinear motion, and uniformly changing rectilinear motion. This lecture teaching activity was carried out during three lectures in class. Researchers also teach computational thinking skills from a theoretical perspective, procedures, and application techniques. At the end of the learning session, the researcher evaluated using a cognitive test in the form of essay questions. Students are allowed to explain the answer to one of the questions of their choice. This is done to see student performance procedures and skills directly. This evaluation analyzes performance results and scores according to the stages of problem-solving performance using computational thinking skills.

Result and Discussion

The spirit of computational thinking skills lies in student's ability to sort, integrate, and design problem-solving patterns. Problems in kinematics have complex sentence structures, often leading to misunderstandings regarding the problem's direction and misconceptions due to the ambiguity of text language as a medium for conveying issues. So computational thinking, which adopts a simplified computer performance system that forms a hierarchical pattern, becomes a priority option in helping solve physics problems. Generally, the higher the cognitive level of a problem, the more complex the solving process is.

This research has found data on students' skills in solving kinematics problems using computational thinking. At the decomposition stage, students break down the problem-solving process into smaller parts that are easy to manage: grouping parts of words with integrated meanings and forming separate concepts. This grouping stage is based on the range of meanings possessed by a combination of words or sentences with a single meaning or multiple meanings that refer to one concept. In the process of dividing case partitions, it is assumed that students have been able to divide the language of kinematics cases into more than three parts.

Students are free to decompose according to the quality of their understanding and analytical power. This is based on the diversity of students' verbal intelligence so that each student works to find effective and practical ways to properly understand a kinematics case sentence according to its true meaning. At the abstraction stage, students filter and sort information only on parts of the case language that are considered essential and have value in solving the problem by ignoring other things that are not important. This is done because a kinematics case does not always display important variables or indicators. However, a case is presented in language that explains concepts and objects by the targets conveyed in the case. Because of these characteristics, the abstraction stage becomes the primary tool to facilitate the analysis process to avoid misconceptions. In this case, errors in abstracting the language and variables cause successive errors in the next phase. In this section, students carry out in-depth meaning analysis to find essential variables and understand the direction of the case and how to solve it.

In the visualization stage, students filter information to find similar problems. Students look for similarities between issues and identify essential patterns that help the problem-solving process. This activity occurs when the case is still in partition or decomposition form. From a partition of multiple statements, Students understand case sentences through a semantic analysis process to identify individual words or phrases and sentences that contain the same meaning in each decomposition group. Students connect semantic understanding and concepts with representations, symbols, patterns, or formulas representing case variables. Because this stage refers to information discovery and coding, students use visualization skills to correlate material concepts with the presented cases. So that the final process in the form of determining the pattern that will be used as one of the stages in solving the problem is carried out precisely and correctly. Pattern determination does not only occur partially but at this stage, the pattern is designed to solve problems that have been put together by finding practical or fast ways.

At the design stage, students use formulas or equations integrated with kinematics concepts to solve problems. Students use a strategy that has been used by many physics students, namely by writing down several known components in the case along with the unit conversions attached to those variables. In the writing phase of the variable representation, several essential keywords that influence the analysis results in the case of kinematics are included. These keywords are additional treatments or explanations that explain the object used as the center of attention in the case sentence. Next, write down the unknown and sought variables. This unknown variable moves students to carry out an in-depth analysis of the stages of completion, followed by a possible formula pattern that can be used. This formula or equation functions as a direct solution or is only one of the stages that an analysis of other equations must follow. Often, the cases presented cannot be solved using just one equation but begin by using another pattern to look for the following unknown variable as a prerequisite for finding the final result or solving the problem.

From this explanation, it can be understood that students have used computational skills in solving kinematics problems at a high cognitive level. This has stimulated students' thinking skills to be bound to specific procedures in conducting analysis and accustomed to using critical and analytical thinking skills to solve problems. The creativity of students' analytical thinking increases through proportional training in using computational thinking skills in learning kinematics. A description of students' computational thinking abilities in solving kinematics cases at a high level of cognitive level is explained in the following table.

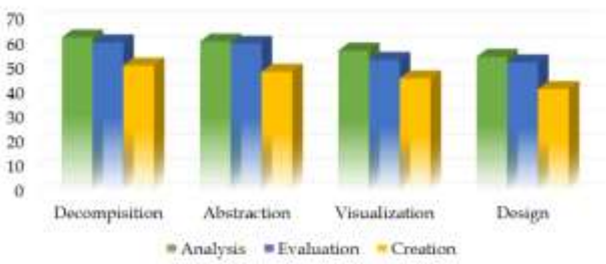

Figure 1. Students' computational thinking skills in solving kinematics cases at the HOTS level

From the details above, it can be understood that the flow of computational thinking is arranged based on a hierarchical arrangement from the initial stage to the final stage. Meanwhile, cognitive indicators are arranged based on a hierarchical order from low-cognitive to high-level cognitive. In the decomposition phase, students' ability to analyze, evaluate, and create changes implies a decreased thinking ability. In the analysis phase, the average student score tends to be higher than at all other cognitive levels, with an average score of 62. Meanwhile, the evaluation phase decreases by more than 10 points and vice versa; the creation phase has the lowest average score.

As is known, the decomposition phase is the stage of partitioning and separating each instrument component for each type of question at the cognitive level. This is because the activity of understanding the case context conveyed in sentences at each cognitive level tends to be different. The differentiating factors come from the characteristics of the operational verbs and the case sentences. The higher the cognitive level, the higher the complexity of the conflict. Thus, students' ability to articulate at the initial stage also tends to be more difficult. Students must understand the context of words and sentences before separating each case context. With the increasingly complex characteristics of case language, student’s ability to carry out decomposition also decreases, even though all students are directed to carry out the decomposition phase well by the directions and instructions given by the teacher.

This decrease in decomposition ability is also the same as what was expressed by Basogain et al. (2018) who explained that decomposition ability is an initial stage that is thought to be easy to carry out. However, if a given case experiences an increase in difficulty, it will change according to the topic. Also, in line with what was found by Juškevičiene et al. (2018) the decomposition phase allows individuals to claim the ease of a task because it is only the initial door to enter a more complicated process. Regarding the use of decomposition in solving physics cases, (Yin et al., 2020) stated that this is the decomposition phase, which is an easy process that only groups physics cases into smaller parts so that difficult things do not appear in this part. So, there are no differences in implications between the results of this research and those found by researchers.

Student abilities performing abstraction at the cognitive level of analysis tend to be higher than 60. Similarly, in the case of student abilities in the decomposition phase, the average student score decreases at the analysis, evaluation, and creation levels. The lowest score at the creator level is below the average of 50, which indicates that students' abstraction abilities and an increase in the difficulty level of the questions have decreased significantly. This decrease is considered normal because cognitive groups form a hierarchy from easiest to most difficult, so students' ability to identify critical points in case sentence fragments also tends to be more complicated and complex. This is caused by students' low understanding of the text and the ambiguous nature of the text in explaining a case or event. Circumstances are difficult to convey in complex sentences. Hence, they require in-depth understanding to identify whether certain words in the case sentence are essential information to solve the problem or are just complementary parts.

In this indicator, it was found that students' abstraction skills were quite varied but were at the average lower middle level; this indicates that students' ability to analyze a sentence to distinguish important components has yet to be optimal. So, students often put sentences and words that are less important into groups of essential variables and ignore other words or phrases due to weak analytical power. This fact indicates that learning and understanding cases are not only related to physics learning problems but more than that depends on understanding words and sentence articulation as well as students' analytical abilities. In line with research Podolefsky et al. (2007) which reveals that abstraction abilities do not stand alone, the results depend on the complexity of the material being analyzed; this indicates that it also depends on the complexity of the cases and problems used as objects (Larkin, 2020), abstraction abilities go hand in hand with manipulation abilities, so (Taub et al., 2014) claim that abstraction abilities cannot be separated from the cognitive component. In the case of high-level cognitive skills, abstraction abilities also increase in difficulty based on the difficulty level.

Students use analytical intelligence to convert case statements into code or symbols at the visualization stage. This is caused by the calculation operations used in kinematics material using specific agreed codes and symbols to facilitate the analysis process. In the visualization process, students analyze each sentence partitioned to identify similarities in each focus sentence. In this process, there has been a conversion process from text into certain symbols that represent the variables used in calculation operations. At this stage, the student's ability to visualize cases at the analytical level is above 70. This value represents the student's ability to visualize physics cases at the cognitive level at the analytical level, which tends to be better than the visualization ability at the next cognitive level.

Kinematics at the evaluation and creation level shows that the average student score is in the low category, namely in the range of 57 to 45. This score is considered at the lower level of mastery of learning outcomes. The low ability of students to visualize in high-level cognitive cases, especially at the evaluation and creation levels, is caused by students' lack of ability to articulate the meaning of words and sentences in general. Students are also not fluent in analyzing the meaning of words in complex cases. Some students still think rigidly, only focus on the explicit meaning of sentences, and cannot analyze hidden meanings. This rigidity affects students' ability to convert case sentences into complete physics concepts, leading to ongoing misinterpretations and misconceptions.

Visualization skills in learning physics are needed as an initial way to understand the problem entirely. Research from Roast et al. (2016) reveals that visualization in physics is also influenced by the level of complexity of the problem, so it still depends on the level of difficulty of the problem at the cognitive level. This aligns with Roast et al. (2016) which state that visualization is integrated with the understanding process and analytical skills. Also, research from De Regt (2001) says that problem visualization in physics lessons is an integrated component with cognitive and psychomotor aspects. Thus, the results of this study are consistent with the results of other studies, which confirm the involvement of elements of visualization, which increase in difficulty along with increasing complexity of circumstances and conditions.

Students' ability to design patterns or code to solve problems also tends to decrease from other stages of computational thinking. At this stage, all aspects in the abstraction and visualization decomposition phase are returned to the original complete case concept. In rectilinear motion kinematics, the solution design refers to the formula or equation used to solve problems designed in high-level cognition. At this stage, students' ability to design solutions and general formulas also decreases at all cognitive levels. The students had the highest score when solving cases at the cognitive analysis level. At this stage, analytical skills Students also have higher evaluation and creation abilities. Students consider that designing new pattern solutions used to solve problems at the analytical cognitive level tends to be easier than at other cognitive levels. At the cognitive level, evaluating and creating gradually and regularly shows a decline in students' ability to design patterns. From the analysis of student performance evidence, quite a lot of significant errors were found. This error is an accumulation of many things that could be corrected. The student stated that designing the right formula requires thinking harder because the sentences used are more complex and complicated because they involve several circumstances. Cases at a high level of cognitive level already use other conditions apart from the general issues at a low level so that the pattern used is not like the general formula explained by the instructor or lecturer. Students stated that in cases at the analysis, evaluation, and creation level, equations or formulas were modified according to the direction of the case question and the conditions used. Students are not only required to analyze case language and physics concepts. Still, they are also required to carry out analysis and modification of equations so that they suit their needs.

Another complexity that students have is the ambiguity of the meaning of the case and the high level of complexity of the given situation. This complexity refers to the use of conditional and gradual formulas or equations. To be able to use certain famous equations, you need to use other equations first because there are prerequisite values that must be obtained. So, students think twice in designing patterns to use these equations in several situations. This difficulty was successfully overcome by students accustomed to analytical and modified thinking. At the design stage, students' ability to solve cases at the analysis level still tends to be higher than cases at other high-level cognitive levels, which are in the score range of 50 on average. Thus, students' ability to design solutions to cases presented at the cognitive level tends to need to be more competent, so ongoing training is required to improve students' abilities.

Thus, it can be concluded that the average student needs to be able to solve cases at a high cognitive level using computational thinking skills. Students can only solve a few issues and use computational thinking skills only at the decomposition and abstraction stages. Meanwhile, students had difficulty doing this at the visualization and design stage. This lack of ability is caused by many factors, mainly the ability to articulate the meaning of case words and sentences and the need for skill in analyzing case variable components. Corrective and preventive actions are needed so that students proficiently implement competitive thinking skills at a high level of cognitive level.

Conclusion

In physics problem-solving procedures on kinematics topics based on computational thinking skills, students can only solve cases well at the decomposition and abstraction stages, while the visualization and design stages experience difficulties at the cognitive levels of analysis, evaluation, and creation. This lack of ability is caused by the low ability of students to articulate the meaning of case sentences and analyze variable components in the case. The mistakes that students most often make are misinterpreting case language, misunderstanding the concept of the problem, determining essential variables in the case, finding hidden problem variables, determining the equations used, and errors in calculation analysis.

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Author Contributions

In this research, all authors have their respective roles; Rabiudin and Erwinestri works in theoretical studies, data collection and data analysis. Tiara and Dian work in proofreading before publication.

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