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Improving Computational Thinking Skills Through The Implementation of Project-Based Learning According to Student Differentiation in Physics Learning

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Abstract: The research aims to determine the effectiveness of project-based learning by paying attention to student differentiation to improve computational thinking skills. The research is based on students' computational thinking skills, which are still below standard, namely below of 50% at each stage, including decomposition, pattern recognition, abstraction, and algorithms. This research is classroom action research carried out over three learning cycles. The results of the research show that there is an increase in students' computational thinking skills in each learning cycle given. In the first and second cycles, the level of achievement of students' computational thinking skills reached 22.8% and 54.29%, meaning that what was originally in the very low category became low. After that, in the third cycle the level of achievement of students' computational thinking skills in the high category reached 88.57%. The gain test results in the first and second cycles were in the medium category with n- gain scores of 0.40 and 0.52. Furthermore, in the third cycle, an n-gain of 0.71 or high category level. These results indicates that the implementation of project-based learning according to student differentiation in physics learning was effective in improving computational thinking skills.

Keywords: Computational thinking skill, Project-based learning, Student differentiation

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Introduction

The Indonesian government has explicitly given instructions to implement the Kurikulum Merdeka starting in the 2022/2023 academic year through the Keputusan Menteri Pendidikan, Kebudayaan, Riset, Dan Teknologi Republik Indonesia Nomor 56/M/2022 concerning Guidelines for Implementing the Curriculum in the Context of Learning Recovery. Dewi (2022) explains that the learning process in the Merdeka Curriculum emphasizes students' skills in solving problems through project activities as one of its main characteristics. Project Based Learning (PjBL) aims to develop problem-solving skills and student character as skills that need to be mastered in the 21st century.

Maharani *et al.* (2019) stated that one possible way to improve problem-solving skills is to improve students' computational thinking (CT) skills. Haseski *et al.* (2018) & Wing (2006) stated that CT is a skill that needs to be mastered by students in the 21st century. In fact, CT has been labeled as a futuristic skill that can equip someone to face work demands and environmental changes that are difficult to predict (Nouri *et al.*, 2020).

Research by Supiarmo *et al.* (2022) actually shows that the CT process of students in Indonesia is still low, namely only reaching the decomposition stage. This result indicates that students in Indonesia are not yet fully able to connect the problems and concepts they have as materials for building solutions. The method for measuring students' CT skills is based on the results of their work on Bebras questions (Nuraisa *et al.*, 2021). Dagienė & Sentence (2016) explained that Bebras questions are designed on the foundations of computational thinking skills, including decomposition, pattern recognition, abstraction, and algorithms. Bebras questions are usually used to stimulate students’ skills in problem solving.

Analysis of the results of measuring computational thinking skills using Bebras questions on twenty respondents at SMA Negeri 2 Bae Kudus shows that the percentage of CT skills in the decomposition, pattern recognition, abstraction, and algorithm stages respectively, is as follows 48.89%, 31.11%, 17.77%, and 0%. This data shows that the CT skills of students at SMA Negeri 2 Bae Kudus are still low because, at each stage, they are still less than 50% (Nuraeni *et al.*, 2018). This indicates that action is needed in order to improve learning to improve students' computational thinking skills, as well as provide provisions for students to be ready to face the challenges of an increasingly complex era.

PjBL is a constructivist learning strategy that expects students not just to memorize their knowledge but also to build on and interpret the new knowledge they have. PjBL allows students to solve problems actively by participating in collaborative activities with other people to reflect on learning (Kizkapan & Bektas, 2017). This is in line with the opinion of Chiu (2020), who supports the idea that higher order thinking skills are not just memorizing facts but can be improved in PjBL activities.

Tseng *et al.* (2013) ensure that projects in PjBL are a development process that allows students to build their knowledge through exploration and provide opportunities to gain meaningful learning from the material that has been taught. In addition, Asunda (2018) emphasized that students who learn through participation in project-based learning activities tend to have the skills to connect various ideas and knowledge. Therefore, PjBL can be said to be in accordance with constructivist learning theory, which allows students to build their understanding through exploration. The relationship between PjBL syntax and CT components is manifested in students' activities during the learning process, as presented in Table 1.

Table 1. Student Activities in PjBL by Accommodating CT Components

Syntax PjBL	CT Components	Students Activities
Start with the essensial question	Decomposition	Students recognize the variables that influence a phenomenon. At this stage, a dilemma will arise for students about putting their findings into real action.
Design a plan for the project	Pattern recognition	Students recognize the pattern of influence of these variables on the observed phenomena. Students determine the value of each variable and the possible changes in value to that variable.
Create Schedule	Pattern recognition	Students plan project implementation based on the pattern of influence of observed variables. Observed patterns help students recognize the product development process they will face.
Monitor the students and the progress of the project	Abstraction	Students generalize various variables in the form of constructions that are ready to be compiled by algorithms. At this stage, students can identify what might happen if these variables change.
Asses the outcome	Algorithms	Students express the abstractions obtained in products that are designed systematically and are easy to understand.
Evaluate the experiences	Algorithms	Students evaluate the results of their performance, improve, and add things related to the performance of the product being developed

Hsu *et al.* (2018) stated that many countries have implemented CT skills in their educational curricula. Therefore, as professional teachers we need to prepare ourselves to face teaching challenges by integrating

CT concepts into subjects with the help of developments in digital technology. Teachers can integrate the project- based learning model (PjBL) in an effort to improve students' computational thinking skills. Therefore, the author realizes that classroom action research related to efforts to improve students' thinking skills through the PjBL model is something that is urgent to do at this time.

Methods

This research is Classroom Action Research (CAR) which is expected to improve the learning as well as investigate improving CT skills through the implementation of project-based learning according to student differentiation in physics learning. Students are given a diagnostic test to determine their characteristics and initial CT skills in the form of a learning style questionnaire and questions adopted from the Bebras Questions, totaling twelve questions, with each stage of CT skills consisting of three questions each. Next, the research subjects were determined using a purposive sampling technique based on a preliminary study, with the average CT skills of students being the lowest compared to other classes, in this case the students at SMA Negeri 2 Bae Kudus class XI MIPA 1. Next, the students were grouped, and the PjBL learning model is given treatment according to the differentiation of student characteristics in a cyclical manner, and then the CT skills of the students were analyzed. Students are given a pre-test and post-test as material for analyzing CT skill improvement.

This CAR was carried out over three months using the PjBL model by paying attention to student differentiation according to the results of the diagnostic assessment of students' learning styles that had been obtained previously. The results of the diagnostic test for differentiation of students' learning styles are used as a reference for educators in mapping students. Students can choose the content, processes, and products they want in their learning process. Walidain *et al.* (2023) stated that differentiated learning helps students solve problems effectively. Prihandini *et al.* (2023) added that learning that pays attention to student differentiation is able to increase active student involvement in learning so that the expected learning objectives can be implemented by paying attention to the differentiation of students' learning styles, including audio, visual, and kinesthetic. The research carried out in three learning cycles, according to the flow diagram in Figure 1.

Research data obtained from students' pretest and posttest scores in each cycle were then analyzed by categorizing the scores obtained based on the students' CT skill criteria, referring to Rasyid *et al.* (2016) to determine whether there was an increase in students' CT skills after implementing the PjBL model in physics learning. These criteria (C) are shown in Table 2.

Table 2. Criteria CT Skills

CT Skills	Criteria
$90{,}0 < C \leq 100$	Very High
$75{,}0 < C \leq 90{,}0$	High
$60{,}0 < C \leq 75{,}0$	Medium
$40{,}0 < C \leq 60{,}0$	Low
$0{,}00 < C \leq 40{,}0$	Very Low

Next, a gain test was carried out on the data to find out how implementation of the PjBL model affected the improvement of students' CT skills. The analysis was carried out using normalized gain calculations using the average normalized gain equation by Hake (2002) as follows.

$$\langle g \rangle = \frac{(\%S_f)-(\%S_i)}{100-(\%S_i)}, \quad (1)$$

where,

$\langle g \rangle$: difficulty index

$\%S_i$: average score pretest

$\%S_f$: average score posttest

100 : maximum score

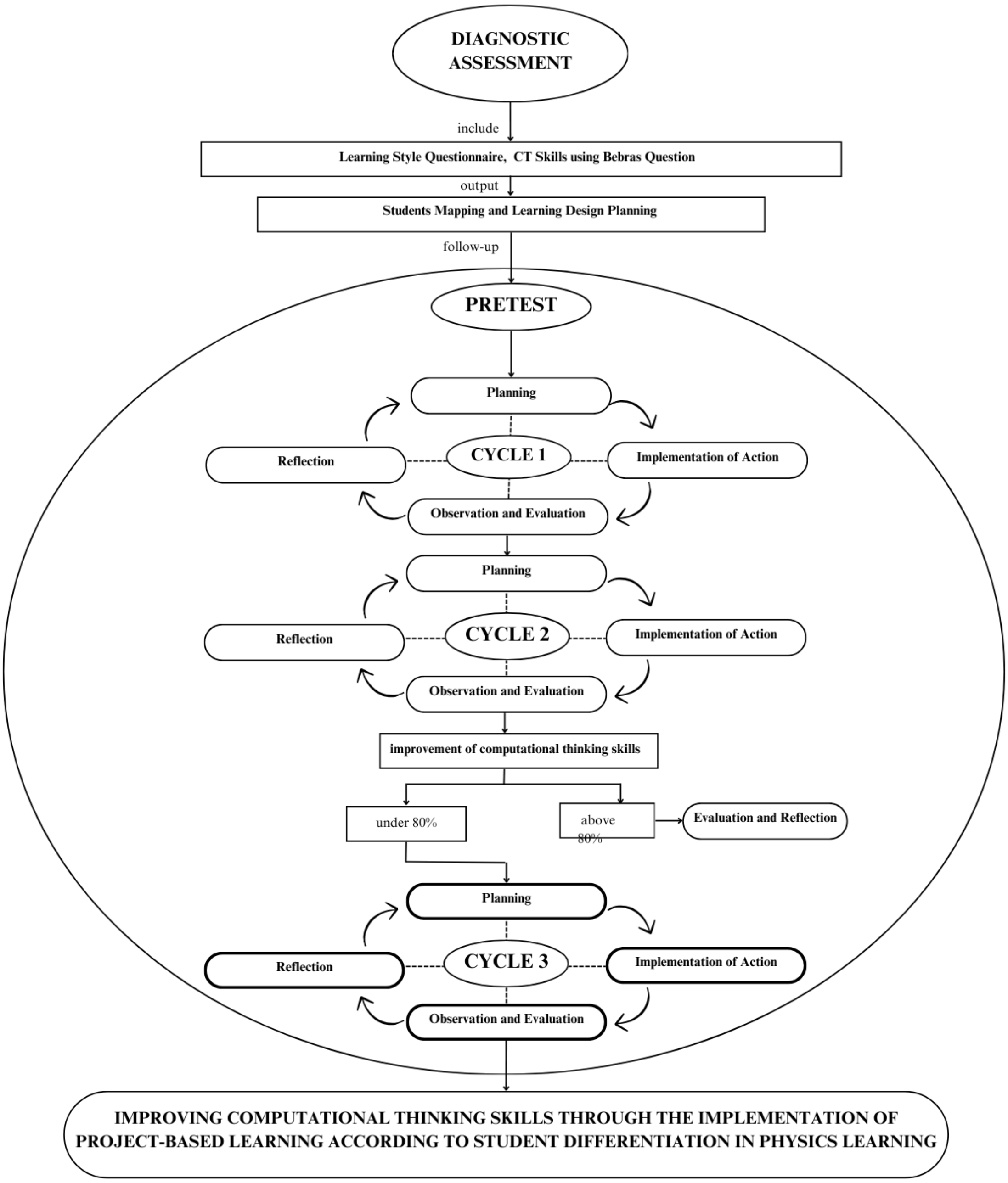

Figure 1. Research Flow Diagram

The gain test results are interpreted according to the criteria referring to Meltzer in Novianto *et al*. (2018) with classification as shown in Table 3.

Table 3. Criteria n-gain

CT Skills	Criteria
$\langle g \rangle > 0{,}7$	High
$0{,}3 < \langle g \rangle \leq 0{,}7$	Medium
$\langle g \rangle \leq 0{,}3$	Low

Results and Discussion

Data on the achievement of students' computational thinking skills scores obtained from the pre-test and post-test scores in each cycle. The data on the achievement of computational thinking skills by class XI MIPA 1 students is shown in Figure 2.

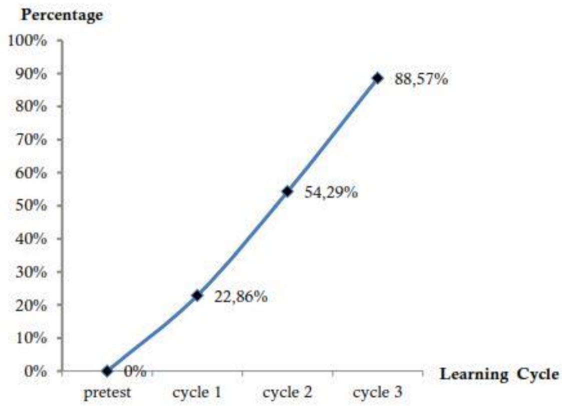

Figure 2. Graph of Students' CT Skills Achievement Each Cycle

Based on the graph of the percentage of students' CT skills achieved, it can be concluded that there is an increase in the level of students' CT skills achievement in each cycle. In cycle 1, students' achievement of CT skills in class XI MIPA 1 was 22.86% and was classified as very low. In the first cycle, the results of the students' CT skills experienced an increase from previously being in the very low category to being low, according to Rasyid *et al.* (2016). The class average in the first cycle was 48, with the lowest score being 30 and the highest score being 77.5. This indicates that there is a significant increase in the learning provided. In cycle 1, with a minimum completion score of 75, there were 7 students who completed it and 28 students who did not complete it. This indicates that although there is improvement in the results of students' CT skills, teachers need to provide learning improvements so that the goal of improving students' skills in the high category can be achieved.

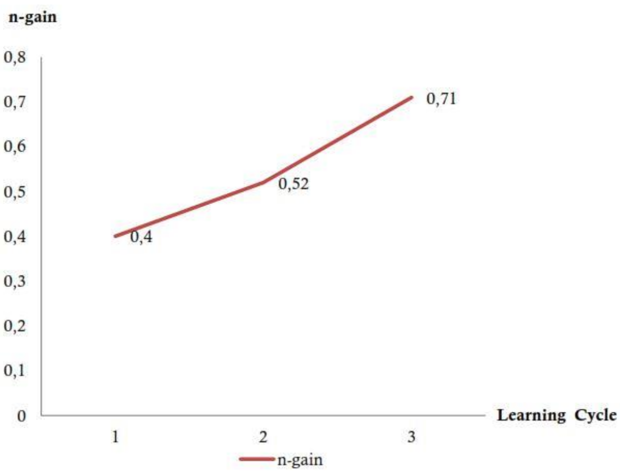

Figure 3. Graph of n-gain Score for Each Learning Cycle

Furthermore, in cycle 2, students' CT skills increased to 54.29% but were still classified as low. In cycle 2, with a minimum completion score of 75, there were 19 students who completed and 16 students who did not complete. This indicates that although there is improvement in the results of students' CT skills, teachers still need to provide learning improvements so that the goal of improving students' skills in the high category can be achieved.

Students' CT skills in the high category can be achieved in cycle 3, with an achievement percentage reaching 88.57%. The class average in the third cycle was 85.4, with the lowest score being 67.5 and the highest score being 95. This indicates that there was a significant increase in the learning provided. In cycle 3, with a minimum completion score of 75, there were 29 students who completed and 6 students who did not complete. This indicates that even though the results of the students' CT skills are in the high category, teachers need to provide remediation to the six students who still have not reached the expected criteria. Data on the percentage of students' CT skills achieved shows that the application of the project-based learning model is effective in improving students' CT skills.

Apart from calculating the percentage of students' CT skills achieved, a gain test was also carried out to determine the n-gain score for CT skills achieved in each cycle. This n-gain score is a reference in determining how much influence or effectiveness the PjBL model has. The n-gain score for each learning cycle in this classroom action research can be seen in Figure 3.

Based on the n-gain score graph, it was found that the n-gain score in cycles 1 and 2 was 0.4 and 0.52 respectively, or still classified in the medium category, so that in both cycles, even though the PjBL learning model provided had an influence on improving students' CT skills, it was not effective enough in helping improve students' CT skills as expected. Furthermore, in cycle 3, the n-gain reached 0.71 and was classified as high. This shows that at the end of cycle 3, the PjBL model classroom action research carried out was effective in improving students' CT skills, so that it can be used as a reference for other educators who are trying to improve students' CT skills.

Conclusion

Based on the results of the research and analysis, it can be concluded that the soil pH in the agricultural land of Gemuhblanten Village for maize plants is 7.75 which is included in the "slightly alkaline" criteria. Meanwhile, in chili plants, soil pH of 7.08 was obtained, included in the "neutral" category. The pH value of the soil in chili plants is still within the range of soil pH requirements for chili growth. Meanwhile, the soil pH value for maize plants was quite high, exceeding the range of good soil pH for maize plants.

Soil quality is one of the important factors that must be considered in plant cultivation, especially if the land is used for cultivating different plants. One way to know the quality of the soil is by measuring the pH or acidity level of the soil. Each plant requires a different soil pH according to the criteria that have been set in order to grow well. Through this research, recommendations or suggestions can be given, such as measuring and adjusting soil pH so that the resulting agricultural products are of good quality.

Based on the research that has been conducted, it can be concluded that the Classroom Action Research (CAR) can improve students' computational thinking (CT) skills. CAR with cyclical implementation of the PjBL model in accordance with student differentiation is effective in improving students' CT skills, so that the PjBL model can be used as a reference for educators in general especially physics educators in an effort to improve students' CT skills and improve the quality of learning provided.

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