Model Implementation Problem-Based Learning with a Differentiated Learning Approach to Improve Abilities, Computational Thinking Student

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Abstract: Based on the results of the non-cognitive diagnostic assessment conducted by the author in class X PPLG 1 SMK Negeri 11 Bandung, the computational thinking abilities possessed by students still need to improve. In addition, based on the results of observations, teachers have not implemented differentiated learning optimally. This study aims to improve students' computational thinking abilities by applying problem-based and product-differentiated learning models. The research method used is Classroom Action Research (CAR), carried out in 3 cycles. The subjects of this study were 20 students of class X PPLG 1. The results of this study show that applying the PBL model and product-differentiated learning can improve student learning outcomes in the DPLG subject, with the achievement of completeness in cycle I at 45%, cycle II at 70%, and cycle III at 45%. Students' computational thinking abilities also increased from achieving completeness of 10% to 75%. The effectiveness of learning carried out in cycles I and II are included in the reasonably practical category, as evidenced by the N-gain of 60% and cycle III of 41%, which can improve students' computational thinking skills.

Abstrak: Hasil asesmen diagnostik non kognitif yang penulis lakukan di kelas X PPLG 1 SMK Negeri 11 Bandung menunjukkan bahwa siswa memiliki kemampuan berpikir komputasi yang kurang. Selain itu, hasil menunjukkan bahwa guru belum menerapkan pembelajaran berdiferensiasi secara maksimal. Dengan menggunakan model pembelajaran berbasis masalah dan pembelajaran berdiferensiasi produk, tujuan penelitian ini adalah untuk meningkatkan kemampuan berpikir komputasi siswa. Penelitian ini dilakukan melalui Penelitian Tindakan Kelas (PTK) dalam tiga siklus, dengan empat tahapan: perencanaan, tindakan, observasi, dan refleksi. Subjek penelitian ini adalah siswa kelas X PPLG 1 sebanyak 20 orang. Hasil penelitian ini yaitu penerapan model PBL dan pembelajaran berdiferensiasi produk dapat meningkatkan hasil belajar siswa pada mata pelajaran DPLG elemen PBO materi *inheritance* dan *polymorphism* dengan pencapaian ketuntasan pada siklus I sebesar 45%, siklus II sebesar 70%, dan siklus III sebesar 45%. Kemampuan *computational thinking* siswa juga meningkat dari pencapaian ketuntasan 10% naik menjadi 75%. Efektivitas pembelajaran yang dilakukan pada siklus I dan II termasuk dalam kategori cukup efektif yang dibuktikan dengan *N-gain* sebesar 60% dan siklus III sebesar 41% sehingga mampu meningkatkan kemampuan berpikir komputasi yang dimiliki oleh siswa.

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A. Introduction

Today's advances in technology and information make it possible to automate all areas of life (Mulyati, 2022). So, quality human resources (HR) are needed to compete globally (Pratiwi, 2020). The quality of vocational schools needs to be improved in various aspects, such as education, skills, and ability to compete in the world of work (Prabowo et al., 2024). Vocational High School (SMK) is a level of formal education that can help improve the quality of human resources because SMK is a vocational school that aims to produce graduates who are ready to work and have skill competencies in specific fields (Lutfia et al., 2024).

One of the areas of expertise at Vocational Schools is Software Engineering, as stated in the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 70 of 2013. One of the subjects studied in this area of expertise is the Basics of Software and Game Programming, elements of oriented programming. Object, materialinheritanceAndpolymorphism.This material is essential for students to study in this area of expertise because it can make it easier to create program code effectively and efficiently (Jolie et al., 2022).

At SMK Negeri 11 Bandung, where researchers carried out PPL II activities, students still needed to gain knowledge and skills related to material inheritance and polymorphism. This is proven by the results of the initial assessment of 20 students. Nineteen students had yet to reach the Minimum Completeness Criteria (KKM) in the material inheritance, and as many as 11 students had yet to reach the KKM in the material polymorphism. Therefore, there is a need for learning that can increase students' knowledge and skills in this material. So that learning can increase knowledge and skills optimally, teachers can implement the concept of differentiated learning (Nafisa & Fitri, 2023).

One type of differentiated learning is product differentiation (Wahyuningsari et al., 2022). By implementing differentiated activities, students are required to produce work or finish a job according to their cognitive level. Teachers can create three levels of cases: low, middle, and high. To truly focus students' learning on working on cases or solving issues the teacher assigns, teachers can utilize a problem-based learning paradigm while implementing differentiated learning. After finishing their level, each student can move on to the next one. This is to make sure that pupils are never bored and never have time to utilize electronics in class.

In solving the given case, students can use one type of problem-solving strategy: computational thinking (CT). Moreover, in the 21st century, CT has become an essential skill that all students must have, along with reading, writing, and counting (Maharani, 2020). So, students at SMK Negeri 11 Bandung need to have CT skills.

The implementation of a problem-based learning model to improve computational thinking abilities by integrating differentiated learning has been carried out by Putri et al (2024). This research was carried out in class. The differentiated learning method is content-differentiated learning because biology subjects are abstract, so varied content presentation is needed so that students can understand the learning material well. Apart from that, to

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understand Biology subjects, you also need problem-solving skills, namely computational thinking. This research shows that the problem-based learning model that integrates differentiated learning significantly affects students' computational thinking abilities. This research has suggestions for further research, namely, the implementation of product differentiation learning.

Other research examining the implementation of problem-based learning models in improving computational thinking skills has also been carried out by Perdana et al (2023), entitled Efforts to Improve Mathematical Computational Thinking Skills Through Problem-Based Learning Models. Students in class VII B of SMP Negeri 14 Surabaya served as the research subjects. Most pupils employed formulas without understanding the concepts when learning mathematics, which spurred the research due to the students' comparatively inadequate computational thinking ability. This was demonstrated during the computational thinking skills test when students were given the surface area of a cube without a lid. However, they wrote the formula for the same surface area, which is equal to the surface area of a cube with six sides. This indicates that students could only memorize the formula and needed to become more familiar with the concept. The study's findings demonstrate that problem-based learning (PBL) emphasizes problem-solving and can help students develop their computational thinking abilities. This study recommends additional research, including customized instruction based on students' interests, to maximize their motivation to learn and develop their computational thinking abilities.

The head of SMKN 11 Bandung's Software and Games Development Department (PPLG) has also suggested using differentiated learning products since, at this school, new differentiated learning is delivered optimally at the class XI level. Product differentiated learning is a type of differentiated learning that is frequently employed in programming courses. This is because, according to its implementation in class XI, it can boost students' motivation and interest in studying, enabling the learning process to proceed as efficiently as possible. Aside from that, SMKN 11 Bandung frequently employs project-based learning, where students are expected to develop programming products. This has led academics to desire to experiment with various learning models to optimize students' problem-solving skills in line with the steps of the computational thinking framework.

B. Method

The population in this research is class. The sampling technique used was probabilistic purposive sampling. Students examining the material inheritance and polymorphism of Object-Oriented Programming in the Basics of Software and Game Development (DPLG) course serve as the sample for this study. Thus, twenty students from Class X at PPLG 1 Vocational School serve as the sample for this study.

To support the planned research, data collecting involves using research equipment. The assessment tools pre-test and post-test computational thinking, as well as the Fundamentals of Software and Game Development assessment instruments, were employed in this study.

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The following formula is used to calculate the completeness of student learning outcomes.

$$P = \frac{F}{N} x\ 100\%$$

Information:
P: Percentage of learning outcomes
F: Number of students who completed
N: Total number of students

Instrument filling results pre-test and post-test, then processed using a gain test. The gain test is used to determine whether there is an increase in student learning outcomes. The formula used to calculate N-Gain namely as follows:

$$N - gain = \frac{Posttest\ score - Pretest\ score}{Maximal\ score - Pretest\ score}$$

The gain test results are then interpreted for effectiveness, as in Table 1 below.

Table 1. Interpretation of Gain Test Results

Percentage (%)	Criteria
<40	Ineffective
40-55	Less effective
56-75	Effective enough
>76	Effective

The data obtained will then be described by comparing the data obtained from each cycle with indicators of the effectiveness of implementing the problem-based learning learning model, as shown in Table 1.

This research was conducted at SMK Negeri 11 Bandung. The type of research used is quantitative research. The research method used is Classroom Action Research (PTK) in 3 cycles. The PTK flow used is as in Figure 1.

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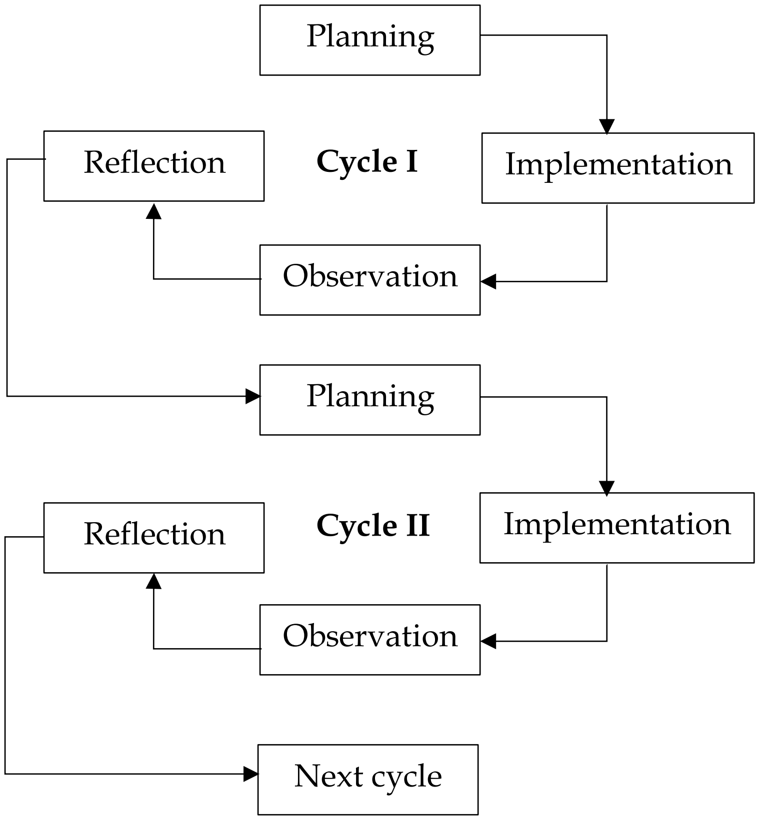

Figure 1. Classroom Action Research Flow (Grasela et al., 2023)

The explanation of the flow of classroom action research in Figure 1 is as follows:

a. Planning Stage

At the planning stage, the researcher prepared several documents that would be used to carry out classroom action research, such as teaching modules, assessment tools, student worksheets (LKPD), and learning reflection sheets. Researchers will also research material, learning methods and models, and differentiated learning concepts that will be applied.

b. Implementation Stage

At the implementation stage, researchers will conduct learning according to the teaching modules that have been created. Learning activities are conducted according to stages, namely preliminary, core, and closing activities.

c. Observation Stage

At the observation stage, the researcher made observations on the results of implementing the learning model problem-based learning and product differentiation learning, as measured by comparing the pre-test and post-test results.

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d. Reflection Stage

At the reflection stage, the researcher will analyze and determine whether the research results are by the research objectives. If the research results are by the objectives, then the next cycle does not need to be carried out, whereas if it is not appropriate, the next cycle must be carried out by students.

C. Result and Discussion

Result

1. Pre-cycle

The pre-cycle results obtained by researchers before carrying out the learning process using the problem-based learning model and product-differentiated learning obtained data regarding learning conditions at SMK Negeri 11 Bandung, especially in the classroom. X PPLG 1 has not optimally implemented differentiated learning, and teachers rarely use the PBL learning model.

In the pre-cycle, researchers also carry out cognitive diagnostic assessments, which use the students' initial abilities in the material inheritance and non-diagnostic assessments to determine the initial abilities of computational thinking students. The results of the cognitive diagnostic assessment are as follows in Table 2.

Table 2. Cognitive Diagnostic Assessment Results

No	Test Results	Mark
1	The highest score	80
2	Lowest Value	0
3	Average value	33
4	Number of students who completed	1
5	Number of students who did not complete	19
6	Percentage of Learning Completeness	5%

Table 2 shows that the cognitive diagnostic assessment yielded the following results: one student completed it, eighteen students did not, and eighteen students did not reach the highest score of 80. The average score was 33. Additionally, the results showed that 19 students had a complete learning experience, and the percentage of students who have abilities computational thinking as much as 5%. The non-cognitive diagnostic examination results are then displayed in Table 3 in the following.

Table 3. Non-Cognitive Diagnostic Assessment Results

No	Test Results	Mark
1	The highest score	100
2	Lowest Value	33
3	Average value	61
4	Number of students who completed	2
5	Number of students who did not complete	18

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No	Test Results	Mark
6	Percentage of Learning Completeness	10%

Table 3 provides information on the results of the non-cognitive diagnostic assessment. Specifically, it shows that two students completed the test, eighteen students did not, and ten percent of students demonstrated computational thinking abilities. The highest score received during the assessment was 100, the lowest was 33, and the average was 61; the number of students who completed was two people, the number of students who did not complete was 18 people, and the percentage of students who had abilities computational thinking as much as 10%.

2. Cycle I

a. Planning Stage

During the planning phase, researchers produced several papers, including teaching material modules, that will be utilized to conduct classroom action research in cycle I. Inheritance, learning reflection papers, student worksheets (LKPD) with instructions on utilizing inheritance to develop a basic program, and cognitive evaluation tools. In addition, researchers have selected a PBL model, produced learning materials in the form of presentation slides, and selected teaching strategies (discussions and assignments).

At the implementation stage, researchers carry out learning activities according to the flow of the teaching module, which includes preliminary, core, and closing activities. The learning is also adapted to the PBL model learning steps. In Cycle I, students were not given differentiated learning but instead asked to complete programming cases in groups.

b. Implementation Stage

At the implementation stage, researchers carry out learning activities according to the flow of the teaching module, which includes preliminary, core, and closing activities. The learning carried out is also adapted to the PBL model learning steps. In Cycle I, students were not given differentiated learning but were asked to complete programming cases in groups. The learning process can be seen in Figure 2 below.

Figure 2. The Learning Process in Cycle I

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In Figure 2, Students are given a programming scenario with a basic calculator that uses inheritance to determine a ball's surface area. Students must use their problem-solving abilities to complete the program by applying computational thinking techniques. These techniques include breaking down the problem, searching for patterns in the answer, performing abstraction, and figuring out the program's algorithm.

c. Observation Stage

At this Stage, researchers used the PBL paradigm to track learning outcomes. Students were given programming cases to work through in groups. Only a tiny percentage of students actively participated in the learning process since it is still evident that some students were preoccupied with using their phones and contributing to their groups during group learning. This will, of course, impact student learning outcomes, as seen in Table 4.

Table 4. Results of Cognitive Aspects of Cycle I

No	Test Results	Pre-test Score	Post-test Score
1	The highest score	80	100
2	Lowest Value	0	50
3	Average value	33	73
4	Number of students who completed	1	9
5	Number of students who did not complete	19	11
6	Percentage of Learning Completeness	5%	45%

Based on Table 4, data calculation results for the pre-test and the post-test in cycle I showed that the class average score was 33, and the post-test amounted to 73. In addition, data was obtained on student learning completion in the pre-test, namely one student, or 5%, who had completed it, while in the post-test, there were nine students, or 45%, who had completed it.

At this Stage, researchers also conducted a gain test on the effectiveness of the learning process. The gain test results are shown in Table 5 below.

Table 5. Cycle I Gain Test Results

	***N-Gain* (%)**
The highest score	100
Lowest Value	0
Average	60

Based on Table 5, the highest N-Gain obtained is 100%, the lowest is 0%, and the average is 60%.

d. Reflection Stage

Based on the results obtained from Cycle I, several obstacles were found, namely the need for more student participation in learning, and there were still students playing on cell

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phones during learning. Apart from that, the average assessment score has not reached the set KKM of 75, and learning completeness is 45% even though learning in cycle I was pretty compelling, as proven by the results gain of 60%. Based on these results, cycle II must be carried out.

2. Cycle II

a. Planning Stage

At the planning stage, researchers have created several documents that will be used to carry out classroom action research in cycle II, such as teaching material modules. Inheritance, cognitive assessment tools, student worksheets (LKPD) containing programming cases created at several levels, and learning reflection sheets. Researchers used the PBL model and discussion and assignment methods.

b. Implementation Stage

At the implementation stage, researchers carry out learning activities according to the flow of the teaching module, which includes preliminary, core, and closing activities. Apart from that, the learning carried out is also adapted to the PBL model learning steps. In Cycle II, students carry out product-differentiated learning, being asked to complete programming cases consisting of three levels: low, middle, and high. Students are asked to work on assignments individually and on cases according to the cognitive level obtained from the results of pre-test cycle II. The learning process can be seen in Figure 3 below.

Figure 3. Learning Process in Cycle II

In Figure 3, students are given product differentiation learning, which is grouped based on pre-test results with the following criteria:

a. Students who get a pre-test score below 60 are included in group A and are given the most straightforward case, namely, making a simple calculator program to calculate the volume of a cylinder.

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b. Students who scored 60 and 70 on the pre-test were included in group B and given a moderate case: to make a simple calculator program to calculate a cylinder's volume and surface area.
c. Students in group C who receive a pre-test score of 80 or higher are assigned a challenging case. The case involves creating a basic calculator program that uses the concepts of branching and inheritance to determine the area and volume of a cone.

Students can work on cases at the next level if they have completed cases at the previous level. I do this to increase their motivation to learn. In this learning, I act as a facilitator tasked with directing and guiding during the case resolution process.

c. Observation Stage

At this Stage, researchers observed learning outcomes using the PBL model and product-differentiated learning, where students were given programming cases that had to be completed individually. At this Stage, it can be seen that when carrying out case-solving, students look active and enthusiastic about solving cases at their level so they can continue solving them at the next level. This will, of course, impact student learning outcomes, as seen in Table 6.

Table 6. Results of Cognitive Aspects of Cycle II

No	Test Results	Pre-test Score	Post-test Score
1	The highest score	80	100
2	Lowest Value	20	40
3	Average value	40	76
4	Number of students who completed	2	14
5	Number of students who did not complete	18	6
6	Percentage of Learning Completeness	10%	70%

Based on Table 6, data calculation results for the pre-test and the post-test in cycle II showed that the class average score was 40 and that the post-test amounted to 76. In addition, data was obtained on student learning completion in the pre-test, namely two students, or 10%, who had completed, while in the post-test, there were 14 students, or 70%, who had completed.

At this Stage, researchers also conducted a gain test to determine the effectiveness of the learning process. The gain test results are shown in Table 7.

Table 7. Cycle II Gain Test Results

	N-Gain **(%)**
The highest score	100
Lowest Value	-100
Average	60

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Based on Table 7, the highest N-Gain obtained is 100%, the lowest is —100%, and the average is 60%. In cycle II, a non-cognitive assessment was given to determine whether there was an increase in computational thinking students. The results of the assessment can be seen in Table 8.

Table 8. Non-Cognitive Final Assessment Results

No	Test Results	Mark
1	The highest score	100
2	Lowest Value	41
3	Average value	80
4	Number of students who completed	15
5	Number of students who did not complete	5
6	Percentage of Learning Completeness	75%

Table 8 shows that when the final non-cognitive assessment was administered, the percentage of students who possessed computational thinking abilities reached 75%. The highest score received was 100, the lowest was 41, and the average score was 80. Of the students who took the test, 15 completed it, five did not, and the average score was 80.

d. Reflection Stage

Based on the results obtained from Cycle II, no obstacles were found during the implementation of Cycle I; in Cycle II, all students participated actively and had a high interest in learning, and no students played on cell phones during learning. The average assessment score has also reached the KKM of 76. Learning completeness is 70%, and learning in cycle II has been quite effective, as evidenced by the achievement of N-gain by 60%. In cycle II, a non-cognitive CT assessment was given to determine whether there was an increase in CT. The result was that 15 people, or 75% of students, had CT abilities. Even though Cycle II was adequate, the researcher still carried out Cycle III to ensure that the PBL model used was effective.

3. Cycle III

a. Planning Stage

At the planning stage, researchers have created several documents that will be used to carry out classroom action research in cycle III, such as teaching material modules. Polymorphism, cognitive and non-cognitive assessment tools, student worksheets (LKPD), which contain steps to create a simple program by applying polymorphism, and learning reflection sheets.

b. Implementation Stage

At the implementation stage, researchers carry out learning activities according to the flow of the teaching module, which includes preliminary, core, and closing activities.

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The learning is also adapted to the PBL model learning steps. In Cycle III, students are asked to complete programming cases in groups. The learning process can be seen in Figure 4 below.

Figure 4. The Learning Process in Cycle III

In Figure 4, students learn in groups to solve programming cases that use the concept of polymorphism. To complete the program, students must use problem-solving skills and computational thinking steps, starting from decomposing the problem, looking for solution patterns, and performing abstraction to determine the algorithm in the program.

c. Observation Stage

At this Stage, researchers observed learning outcomes using the PBL model, where students were given programming cases that had to be completed in groups. However, obstacles exist, namely the unavailability of adequate learning space and a lack of learning facilities and infrastructure because the computer lab is used to carry out Competency Tests. Of course, this will impact student learning outcomes, as seen in Table 9.

Table 9. Results of Cognitive Aspects of Cycle III

No	Test Results	Pre-test Score	Post-test Score
1	The highest score	100	90
2	Lowest Value	20	20
3	Average value	48	70
4	Number of students who completed	2	9
5	Number of students who did not complete	18	11
6	Percentage of Learning Completeness	10%	45%

Based on Table 9, data calculation results and the post-test in cycle III showed that the class average score was 48, and the post-test amounted to 70. In addition, data was obtained on student learning completion, inpretestnamely two students, or 10%, who have completed, while in the post-test, there are nine students, or 45%, who have completed.

At this Stage, researchers also conducted a gain test on the effectiveness of the learning process. The gain test results are shown in Table 10, following:

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Table 10. Cycle III Gain Test Results

	N-Gain **(%)**
The highest score	100
Lowest Value	-100
Average	41%

Based on Table 10, the highest N-Gain obtained is 100%, the lowest is—100%, and the average is 41%, included in the less effective learning category.

d. Reflection Stage

Based on the results obtained from Cycle III, many obstacles were caused by the need for more available learning space, learning facilities, and infrastructure. The average assessment score has not reached the KKM, namely 70, and learning completeness is 45%, and learning in cycle III is less effective, as evidenced by the results N-gain by 41%. Obstacles in implementing cycle III affect learning outcomes because learning facilities greatly influence student learning development. Students use learning tools to help their learning process, such as study rooms, the atmosphere of the study area, learning tools, and lighting. Learning facilities have a significant influence on student learning achievement. Because the more complete the learning facilities they have, the more students can learn well (Rahayu & Purnomo, 2021).

Discussion

The research has obtained results that show the use of learning models, and problem-based learning can improve students' computational thinking abilities. This aligns with research conducted by Manullang & Simanjuntak (2023), which concluded that the problem-based learning model significantly influences computational thinking abilities. When compared with conventional models, learning model problem-based learning can further improve students' computational thinking skills (Pratiwi & Akbar, 2022).

However, when implementing cycle III, there was a decrease in student learning outcomes due to the unavailability of adequate learning facilities, such as computer equipment that would be used for programming. Research conducted by Satriaman et al (2018) shows that complete learning facilities will help students learn, and a lack of learning tools or facilities will hinder their learning progress. The lack of student learning facilities can hinder students' academic development (Umar & Widodo, 2022).

Apart from that, implementing differentiated learning has also helped improve student learning outcomes because, with differentiated learning, students become more active and enthusiastic in learning. This is due to research conducted by Yanti et al (2022), which concluded that the application of differentiated learning had an impact on changing student behavior in learning. From the results of observations, students are more active in learning activities and creative in carrying out assignments so that student learning outcomes can improve. There are several types of differentiated learning, including product

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differentiation, which can improve student learning outcomes (Iskandar, 2021). Product-differentiated learning can improve student learning outcomes because it can help students redefine or expand what they have learned over a certain period (Swandewi, 2021). In order to maximize learning outcomes, before implementing product-differentiated learning, teachers must pay attention to the needs of each individual (Sutrisno & Hernawan, 2023).

D. Conclusion

Based on the classroom action research process, which was carried out in 3 cycles, the researcher concluded that learning using the problem-based learning model in collaboration with product-differentiated learning can improve students' computational thinking skills because, during learning, students are given various cases or programming problems, which must be solved using problem-solving steps in computational thinking which include decomposition, pattern recognition, abstraction, and algorithms so that students can complete the program well and efficiently.

The results of this research can be used as a reference for teachers, especially at the vocational high school level, in using problem-based learning models and product-differentiated learning to improve students' computational thinking abilities. With this research, teachers can consider using learning models according to the abilities expected to be achieved by students. This research is also helpful for teachers in planning differentiated learning that can facilitate the differences in students' needs and abilities.

The research that has been carried out certainly needs to be improved. The effectiveness of the learning process in cycle three decreased due to the unavailability of adequate practicum facilities and infrastructure, hampered the process. Based on this, the researcher hopes that further research can consider various possibilities that can occur during the learning process and can prepare ways to overcome them so that the learning process can take place effectively despite obstacles during its implementation.

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