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The Effect of Differentiated Learning in Problem Based Learning on Cognitive Learning Outcomes of High School Students

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Abstract: This study aims to investigate the effect of differentiated learning in the Problem Based Learning model on the cognitive learning outcomes of high school students. This research uses a quasi-experimental approach with a Nonequivalent Control Group research design. The research sample was selected using a purposive sampling technique with a total sample of 70 students of class X in one of senior high schools in Cimahi city, Bandung. The instrument used consisted of 4 reasoned multiple choice questions about momentum and impulses to measure students' cognitive learning outcomes. The results showed that the average value of N-Gain in the experimental class was 0.81 in the high category and in the control, class was 0.42 in the medium category. Statistical results show that the value of Asymp.Sig is 0.00 > 0.05. That is, there is an effect of differentiated learning in the Problem Based Learning (PBL) model on the cognitive learning outcomes of high school students on physics material.

Keywords: Differentiated learning; Problem based learning; Cognitive learning outcomes.

Introduction

In classroom learning, an educator will certainly find many differences from each student, starting in terms of previous experience, background knowledge, learning methods, potential, interests and learning styles (Al-Shehri, 2020). The philosophy of education thought according to Ki Hajar Dewantara revealed that "Children live and grow according to their own nature, educators can only care for and guide the growth of that nature". This shows how an educator must be able to maintain and guide students to develop every potential that already exists. The education provided is able to guide all the natural strengths that children have in achieving their success (Herwina, 2021). Therefore, educators can only guide the growth of these natural strengths so that children can find their independence in learning. Educators have a responsibility to ensure that students are able to engage in learning by identifying their preferred method and considering their preferred learning style (Al-Rashud & Nawfal, 2017). So, in meeting these needs, differentiation learning is a solution in grouping students based on their learning style needs.

Differentiated learning is an effective learning process that considers the differences of each student in increasing their potential according to the readiness, interests and learning profile of students (Tomlinson & Imbeau, 2010). Tomlinson (2001) reveals that if the learning tasks obtained by students are in accordance with their abilities and understanding and are able to encourage students to do them in the way they like, then students can learn better. In differentiated learning, teachers use time flexibly, apply various instructional strategies, and become partners for students to see that everything they learn from their learning environment can support the learning process (Tomlinson, 2017). The differentiation learning is able to provide opportunities for students to show what they understand (Mulyawati et al., 2022) and are recognized as effective learning to achieve maximum student learning outcomes. (Variacion et al., 2021), especially in students' cognitive learning outcomes.

Cognitive ability is an ability related to the mastery of students in the cognitive domain. According to

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Anderson & Krathwohl (2002), the realm of cognitive abilities contains behaviors that emphasize intellectual aspects, such as knowledge, and thinking skills consisting of Lower Order Thinking Skills (LOTS) and Higher Order Thinking Skills (HOTS). Hardianti (2018) states that analyzing the cognitive abilities of students is important to help teachers know the achievement of learning outcomes and the level of achievement of students' cognitive abilities during the learning process, one of which is in learning physics.

Physics is a branch of Natural Sciences that consists of a collection of facts, natural phenomena, and the results of human activities in the form of ideas, knowledge, and concepts that are organized through a scientific process so that they have a close relationship with everyday life (Pianda, 2018). Students who study physics require broad and deep mastery of concepts. Naf'atuzzahrah (2022) revealed that mastery of concepts in physics learning is one of the important aspects to be improved in order to measure student learning outcomes. While the cognitive learning outcomes of students on physics material are still relatively low and students still have difficulty understanding physics lessons. This is caused by one of the internal factors that can affect students' cognitive learning outcomes, namely learning styles (Busyairi et al., 2021). According to Arends (2008), students have different learning styles according to the level of cognitive development. Only a learning style that suits them can help in understanding knowledge and absorbing information from each material they learn. Students' understanding of physics concepts will certainly have an impact on skills in solving a problem (Melawati et al., 2022). One learning model that is able to develop problem solving skills is the Problem Based Learning model. The PBL model provides opportunities for students to gain knowledge and concepts that are the core of physics subject matter through problem solving activities. In addition, students can also build their own concepts or principles that integrate previously understood skills and knowledge through problem-based learning (Rusman, 2011). The concept that has been understood helps students to have better cognitive learning outcomes.

Thus, to meet the needs of students' learning styles that can improve their cognitive learning outcomes, a study was conducted on the application of differentiated learning in the PBL model. This study aims to investigate the effect of differentiated learning in the Problem Based Learning model to improve cognitive learning outcomes of high school students on physics material. This study focuses on measuring the effect of differentiated learning on cognitive learning outcomes according to Bloom's taxonomy in the Problem Based Learning (PBL) model. The differentiation in this study is based on the profile of the learner's learning style.

Method

Research Design

This research uses a quasi-experimental approach with a Nonequivalent Control Group research design. In this design, it is used in an existing class, so that the sample is not chosen randomly (Creswell, 2014). This study was divided into two classes, namely the experimental class which carried out teaching and learning activities using differentiation learning in the PBL model and the control class which carried out teaching and learning activities using the PBL model only.

Sampling

The population in this study is located in one of the senior high schools in Cimahi City, Bandung. The research sample consisted of two class X majoring in Mathematics and Natural Sciences selected from the population using purposive sampling technique. This sample is 70 students in class X which consists of 35 students in the experimental class and 35 students in the control class.

Instrumentation

This study uses an instrument in the form of cognitive learning outcomes ability tests to measure students' cognitive learning outcomes after learning activities are carried out. This instrument consists of 4 reasoned multiple choice questions regarding momentum and impulse material with five choices of answers. Cognitive learning outcomes ability test is used to determine the achievement of aspects of learning outcomes in the cognitive domain which refers to the cognitive domain according to Bloom's Taxonomy. The instrument used has been empirically validated using the Bivariate Pearson assisted by SPSS by producing a value ranging from 0.41 to 0.55 which is categorized as moderate. The reliability value is calculated using Cronbach's Alpha assisted by SPSS which produces a value of 0.80 in the high category.

Data Analysis

Quantitative data was carried out on students' scores in choosing the answer options for the pretest and posttest. Analysis of quantitative data regarding the improvement of cognitive learning outcomes was carried out by calculating the normalized gain (N-gain). Normalized Gain data obtained from using the equation 1.

$$\langle g \rangle = \frac{\langle Spost \rangle - \langle Spre \rangle}{100 - \langle Spre \rangle} \tag{1}$$

The results of the N-Gain calculation obtained will then be classified into Table 1.

Table 1. Interpretation of N-Gain Score

Range	Category
N-Gain > 0.70	High
0.30 < N-Gain < 0.70	Medium
N – Gain < 0.30	Low

Meanwhile, quantitative data analysis regarding the effect of the differentiation approach on improving cognitive learning outcomes is by statistical testing previously carried out normality test and homogeneity test as a prerequisite in determining the type of statistical test, then accompanied by calculation of effect size to find out how strong the influence is. an effect size calculation is carried out using the Cohen (1998) formula as follows:

$$d = \frac{|M_E - M_K|}{SD_{pool}} \text{ ; dengan } SD_{pool} = \sqrt{\frac{SD_E^2 + SD_K^2}{2}} \quad (2)$$

The value of effect size (d) obtained will then be interpreted according to Cohen's (1998) criteria contained in Table 2.

Table 2. Interpretation of Effect Size

Effect Size	Interpretation
d < 0.2	Very Small
0.2 ≤ d < 0.5	Small
0.5 ≤ d < 0,8	Medium
0.8 ≤ d < 1.0	Large
d > 1.0	Very Large

Result and Discussion

Improving Students' Cognitive Learning Outcomes

This section presents the improvement of students' cognitive learning outcomes between before and after learning using the differentiation approach in the PBL model and learning using the PBL model only. The increase in students' cognitive learning outcomes can be obtained from the data of the pretest, posttest, and normalized gain average <g>. The pretest, posttest and N-Gain cognitive learning outcomes in the experiment class and control class are shown in Table 3.

Table 3. Descriptive Statistical Data Pretest, Posttest and N-Gain

Class	Average Score		
	Pretest	Posttest	N-Gain
Experimental (Differentiated+PBL)	30.00	87.86	0.81
Control (PBL)	23.57	56.07	0.42

From Table 3, it can be seen that the pretest results of the two classes have a low average score of cognitive learning outcomes, which are 30.00 and 23.57, respectively, where there is no significant difference. This means that both classes have approximately the same level of ability.

As for the experimental class after differentiated learning in the PBL model, the cognitive learning abilities of students increased with the marked result of an average posttest score of 87.86. Meanwhile, in the control class, which carried out learning using PBL without differentiated learning, the average posttest score was 56.07. So that the difference between the pretest and posttest scores in the experimental class and the control class are 57.86 and 32.50, respectively. The difference in the value of the two shows a significant result but is not higher than the experimental class that applies differentiation learning in the PBL model. This is in line with what Suwartiningsih (2021) stated that the application of differentiated learning can improve student learning outcomes from the achievement targets that have been set in science subjects. Al-Shehri (2020) also stated that there was an increase in student learning outcomes in academic abilities after receiving learning using a differentiation approach. This is shown from the results of the average learning outcome score of the experimental group which is higher than the control class.

The increase in students' cognitive learning outcomes can also be seen from the results of the normalized average gain in the experimental class and control class, with each value being 0.81 in the high category and 0.42 in the medium category. This shows that the cognitive learning outcomes of students in the class that were differentiated in PBL experienced a more significant increase than the cognitive learning outcomes of students in the class that was not differentiated. These results are also in accordance with the results of the average N-Gain based on the learning style groups in the experimental class and control class as shown in Figure 1.

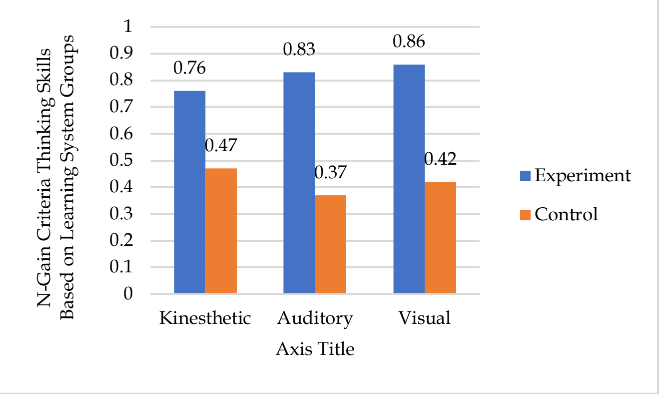

Figure 1. Average N-Gain by Group of Learners' Learning Styles

Before being given treatment in the class where differentiation learning was carried out, students were given a learning style test to determine the type of student learning style and then grouped according to their learning style. As for the class where learning is not done differentiation, learning style tests are also given with the aim of knowing the learning styles of students in the control class without grouping according to learning styles (differentiation). This is done so that researchers know the comparison of the increase in cognitive learning outcomes between the experimental class and the control class in the group of students with the same learning style.

Figure 1 shows that the average N-Gain in each learning style group in the experimental class has a greater value than in the control class. This shows that students who differentiate in the PBL model experience better cognitive learning outcomes on momentum and impulse material than students who learn using the PBL model alone without differentiation. The average N-Gain is the largest among the learning style groups in the two classes, namely in the visual learning style group in the class that is differentiated in PBL, with a value of 0.86 which is in the high category. That is, the increase in cognitive learning outcomes of students who have a visual learning style in the experimental class is superior to other learning styles. This is in line with research conducted by Rambe & Yarni (2019) that visual learning style is one of the learning styles that affect student learning achievement. Students who have a visual learning style are better able to understand the material presented in the form of writing, charts, graphs or pictures (Ahmadi & Supriyono, 2004). This helps students to focus their attention and concentration on the concepts of the material being studied so that it can affect their cognitive learning outcomes.

Overall, the differentiated learning based on students' learning styles is able to improve cognitive learning outcomes on momentum and impulse materials. In line with Astiti et al, (2021) who revealed that mastery of learning styles and the appropriate use of learning styles by students will greatly assist students in absorbing and understanding material information obtained so that it will have an impact on good learning outcomes. In addition, learning style is one of the factors that are considered important in learning because it can affect student learning outcomes, especially learning outcomes in the cognitive domain.

The Effect of Differentiated Learning on Cognitive Learning Outcomes

The data obtained cannot be concluded only from descriptive results, but statistically different tests need to be carried out. To perform the difference test, first, normality and homogeneity tests are carried out as prerequisites in determining the type of difference test to be carried out. After the pre-requisite test was performed, it was found that the pretest and posttest data were not normally distributed and the data variance was not homogeneous, so the Mann-Whitney test was used. The decision-making criteria used are if Sig. > 0.05 then H_0 is accepted and if Sig. < 0.05 then H_0 is rejected.

First, a different test was conducted on the pretest data to determine the differences in the cognitive learning outcomes of students in the experimental class and the control class before learning was carried out. Where the hypothesis is H_0 = there is no significant difference in the pretest of cognitive learning outcomes between the experimental class and the control class. The results of the different test data for pretest and posttest are shown in the Table 4.

Table 4. Results of the Difference between Pretest and Posttest in Students' Cognitive Learning Outcomes

	Pretest	Posttest
Mann-Whitney U	514.000	205.500
Asymp. Sig. (2-tailed)	.214	.000

Table 4 in the pretest results section shows that the Asymp value. Sig. (2-tailed) > 0.05 so that H_0 is accepted. So, the conclusion is that there is no significant difference in the pretest of cognitive learning outcomes between the experimental class and the control class. Therefore, it can be said that the two groups have the same level of understanding so that the comparison of the increase can be calculated.

After being given a pretest and a learning style test, the experimental class and the control class were given treatment. The difference in treatment given to each class lies in the Student Worksheet. In the experimental class, the worksheets given are more diverse and adapted to the group's learning style. For groups whose learning style is visual dominant, the worksheets obtained tend to contain more information and activities arranged in the form of written descriptions/story and pictures. It is intended that students gain more knowledge and concepts of physics through the sense of sight. As for the group whose learning style is auditory dominant, the Student Worksheet obtained contains information and activities that involve the sense of hearing more, such as recording/audio. For groups with a kinesthetic dominant learning style, students get Student Worksheet which guides students to do more practical activities. Every knowledge and physics concept that has been understood through each activity contained in the Student Worksheet, it is hoped that students will be able to solve the physics problems given at the beginning of the PBL model stage (student orientation to the problem).

Meanwhile in the control class, the Student Worksheet given to each student is the same and students are not grouped based on their learning style (grouped randomly). The first treatment in the experimental class and control class students were given Student Worksheet regarding the momentum material, the second treatment was about the impulse material, and the third meeting was about collisions and the law of conservation of momentum. Then at the last meeting, students were given a posttest to find out the cognitive learning outcomes of students on momentum and impulse material after being given treatment.

Then a different test was conducted on the posttest data to determine the effect of the differentiation approach in the PBL model on student learning outcomes on momentum and impulse material. The hypothesis is H_0 = there is no significant difference in posttest cognitive learning outcomes between the experimental class and the control class. These results are shown previously (see Table 4).

Based on Table 4 in the posttest results section, it was obtained that the Asymp value. Sig. (2-tailed) < 0.05 so H_0 is rejected. then the conclusion is that there is a significant difference in posttest cognitive learning outcomes between the experimental class and the control class. This means that there is an effect of the differentiation approach in the PBL model on student learning outcomes on momentum and impulse material. So the results show that the differentiated learning in the PBL model is able to produce better cognitive learning outcomes for students compared to classes that only do PBL learning without differentiation. This is in accordance with the results of the effect size calculation shown in Table 5 in seeing how strong the influence of differentiation learning in the PBL model on students' cognitive learning outcomes.

Table 5. Recapitulation of Effect Size of Differentiation Learning on Cognitive Learning Outcomes

Class	N-Gain	St. Dev	Effect Size	Criteria
Experimental	0.81	21.88	0.92	Large
Kontrol	0.42	16.93		

Table 5 shows that the power of differentiation learning in the PBL model to improve students' critical thinking skills is in the large category with a value of 0.92. It means, the differentiation approach in the PBL model is able to have a considerable influence on increasing students' critical thinking skills. In line with what Magable & Abdullah (2020), Bal, (2016), Faiz et al., (2022), Dunn & Honigsfeld, (2013) and Wahyuni (2022) stated that differentiation learning has a big influence on improving student learning outcomes. Herwina (2021) also explains that differentiated learning is able to help students achieve optimal learning outcomes, because the products they will produce are according to their interests and learning styles, even differentiated learning is considered able to increase students' learning motivation (McAdamis, 2001), (Demir, 2016), Haelermans, (2022). This is because students are very happy and like learning that is carried out by flexible grouping in a differentiated learning.

According to Hapsari (2018), Puspitasari and Walujo, (2020), Berry and Bueno, (2019), this is because students like learning that is carried out by flexible grouping in a differentiation approach. The grouping is able to make it easier for students to discuss and ask questions when they have difficulty or there is a material that they do not understand at the same time. So that this does not make students feel bored and their work in solving problems, especially becomes easier because they have the same learning style. From the convenience obtained by students through problem solving discussions, it certainly leads students to be easier also in understanding the material they are studying.

Conclusion

In this study, differentiation was carried out based on the profile of the learning style possessed by students. This approach is carried out in a Problem Based Learning (PBL) model. The results showed that there was an increase in students' cognitive learning outcomes after differentiated learning in the PBL model on momentum and impulse materials. This can be seen from the average value of N-Gain in the class that is differentiated in the PBL model, which is 0.81 in the high category and in the class that is not differentiated is 0.42 in the medium category. From these results, it can be seen that the differentiation approach in the PBL model is more effective in improving students' cognitive learning outcomes compared to learning without differentiation in PBL. Overall, it can be concluded that there is an effect of the differentiated learning in the Problem Based Learning (PBL) model on the cognitive learning outcomes of high school students in physics. This differentiated learning is highly recommended to be carried out in the classroom by every teacher at every level of education from junior high school, senior high school to university.

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