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Implementation of Differentiation in the *Discovery Learning* Model to Improve Student Learning Outcomes on Newton's Law Topics

Neli[1,2], **Haratua Tiur Maria**[1] **and Erwina Oktavianty**[1]
[1]Departement of Physics Education, Tanjungpura Universitas , Jl. Prof. Dr. H. Handari Nawawi, Pontianak, Kalimantan Barat

[2]E-mail: neliii6777@gmail.com

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Abstract. This study aims to determine the improvement in students' learning outcomes on Newton's Laws material at SMA Kemala Bhayangkari 1 Kubu Raya, through differentiated learning using the discovery learning model. The research design employed is a quasi-experimental design with a nonequivalent control group design. The research sample consisted of Class XI Physics 1 and Class XI Physics 2, each with 31 students, selected using the intact group random sampling technique. The instrument used was a test. The data were analyzed using descriptive and inferential statistical analysis techniques. In the pretest, the experimental class obtained a score of 25.16, and the control class 15.48, both falling in the low category. After the treatment, the experimental class's posttest score increased to 84.83 (high category), while the control class reached 50 (medium category). Based on Cohen's d effect size value, the effectiveness of implementing differentiated learning with the discovery learning model in improving learning outcomes was 2.042, which falls into the high category. In addition, based on a learning style questionnaire, 20 students preferred the auditory learning style. This study concludes that the implementation of differentiated learning using the discovery learning model is effective in improving students' learning outcomes on Newton's Laws material.

Keywords: differentiated, discovery learning, learning outcomes

1. Introduction

Education has an important role in improving the quality of human resources (HR). Ki Hajar Dewantara stated that "Education is the power of effort to advance the growth of character (inner strength, character), mind (intellectual), and body of children." This thinking emphasises the importance of respecting the uniqueness and development of each learner. Although he did not explicitly propose differentiated learning, this concept is in line with his views [1].

To improve the quality of education, the Indonesian government implemented the Merdeka Curriculum. This curriculum gives teachers the flexibility to adapt learning to the needs and characteristics of students[2]. The Merdeka Curriculum is designed to be simpler and more flexible, and provides space for strengthening the character and competency development of students by the Pancasila Learner Profile [3].

The Merdeka Curriculum is designed to be simpler and focus on strengthening character and developing student potential. This shows that this curriculum not only pursues cognitive aspects, but also emphasises the importance of holistic education [4]. This curriculum is the basis for learning innovations, including differentiation. The Merdeka Curriculum also encourages teachers to be more creative and innovative in delivering material. But in reality, the implementation of this curriculum in the field still faces many challenges. One of the main challenges is seen in the physics subject, which is often considered difficult due to the conventional teaching approach [5].

Many students feel that physics is difficult to understand due to the dominance of the lecture method, the large number of formulas, and the lack of contextual material. As a result, students' motivation to learn is low, which has an impact on unsatisfactory learning outcomes [6]. Therefore, a learning approach that is more active, interesting, and in accordance with the way students learn is needed so that the understanding of physics concepts increases. Each student has a different learning style, ranging from visual, auditory, to kinesthetic. This diversity requires teachers to not only use one method, but to combine various suitable learning strategies. With an adaptive and diverse approach, all students can learn optimally according to their characteristics [7].

Based on an interview with the physics teacher at the school, it is known that the lecture method is still dominant and the average score of students only reaches 60, while the school's target score is 75. Therefore, this research is important to do with the aim of knowing whether the implementation of differentiated learning on the discovery learning model is effective in improving students' learning outcomes on Newton's Law material.

2. Methods

The research design used in this research is an Experimental design with the form of a Nonequivalent Control Group Design. Quasi-experimental design has a control group, but it cannot fully control outside variables that can affect the implementation of the experiment [8]. In this research design, researchers used one control group and one experimental group, which began with giving a pretest to each group and ended with a posttest.

This research was conducted at SMA Kemala Bhayangkari 1, Kubu Raya, with a population of 93 students consisting of three classes, namely XI Physics 1, XI Physics 2, and XI Physics 3. From this population, the sampling technique used was an intact group random sampling technique. The sample in this study was class XI Physics 1, which was used as an experimental class, and class XI Physics 2, which was used as a control class, with each class totalling 31 students. As for the documentation study technique in this study, in is the form of notes, photos, files, or learning artefacts related to the focus of research.

The data collection techniques used in this study are measurement techniques (tests), documentation study techniques, and questionnaire techniques. For measurement techniques (tests), namely scoring the answers to the initial test questions and the final test of students. The initial technique aims to determine the learning outcomes of students before implementing differentiated learning with the discovery learning model. The final test to determine the learning outcomes of students after the implementation of differentiated learning with the discovery learning model. The questionnaire technique was used to obtain data on the learning style of students before implementing differentiated learning with the discovery learning model. The questionnaire used in this study is a learning style questionnaire consisting of 14 items on audio, visual, and kinesthetic. The instruments used in this study were test questions and questionnaires.

The validity level of the learning outcomes test and teaching module obtained is 1.00 with a high category. Meanwhile, the validity of the learning style questionnaire consists of 14 items of questions used, consisting of audio, visual, and kinesthetic, and gets a value of 0.78 with a high category.

The steps of this study began with determining the research design, namely, using a pseudo-experiment involving two classes, namely the experimental class and the control class. Furthermore, researchers identified the learning styles of students through special instruments to find out whether students belong to the visual, auditory, or kinesthetic learning style category. Based on the identification results, learners were then divided into mixed learning groups consisting of a combination of the three learning styles equally. In the next stage, the application of the discovery learning model combined with differentiated learning was conducted in the experimental class, while in the control class, the expository method was used.

The learning process in the experimental class was carried out in stages in the discovery learning model, namely through six phases: stimulation, problem statement, data collection, data processing, verification, and generalization. After the learning process took place, data on student learning outcomes were collected through pretest and posttest tests. The data obtained was then analysed using statistical

tests, such as the t-test, to determine whether there was a significant difference between the experimental and control classes. The last step in this research is to compare the learning outcomes between the two classes to conclude the effectiveness of the application of the discovery learning model with a differentiated approach based on learning styles.

The data analysis used in this study is the learning outcomes of students before and after being given treatment on Newton's Law material. Data were collected through pretest and posttest, then given a score according to the assessment rubric and converted to a percentage to determine the level of understanding. Learning outcomes are categorized based on the percentage score range of learning outcomes at the time of the pretest and posttest to determine the increase in learning outcomes according to equation 1.

$$Average = \frac{Total\ Score\frac{pre}{post}}{Total\ number\ of\ students} \times 100\% \quad (1)$$

The improvement of learning outcomes is measured using the N-Gain Score, which shows the effectiveness of learning with low, medium, and high categories formulated by equation 2.

$$N - Gain = \frac{(Post\ test\ score - pre\ test\ score)}{(Ideal\ score - Pre\ test\ score)} \quad (2)$$

The difference in the average improvement of learning outcomes is tested using the two means equality test (t-test) if the data is normal and homogeneous, or the U-Mann-Withney test if not. The decision is based on the significance value (sig), where if sig <0.05, then there is a significant difference between the control class and the experimental class using the t-test.

To determine the effectiveness of the implementation of differentiated learning in the discovery learning model in improving the learning outcomes of students in class XI SMA Kemala Bhayangkari 1, Kubu Raya, on Newton's Law material, the effectiveness can be calculated using the effect size formula from Cohen adopted by Glass in equation 3.

$$ES = \frac{\bar{\bar{Y}}_E - \bar{Y}_C}{Sc} \quad (3)$$

where ES is the effect size,$\bar{\bar{Y}}\bar{\bar{E}}$ is the average value of the experimental class posttest,$\bar{Y}$c is the average value of the control class posttest, whileSC is the combined standard deviation of the two classes.

3. Result and Discussion

This study aims to determine the effectiveness of differentiated learning with a discovery learning model on improving student learning outcomes on Newton's Law material at Kemala Bhayangkari 1 Kubu Raya High School. Before being given treatment, a pretest was conducted in the experimental class and control class to determine the level of initial mastery of students on Newton's Law material. After that, the experimental class was given treatment using a differentiated learning model with a discovery learning approach, while the control class used a conventional model. The posttest results showed an increase in scores in both classes, but the increase in the experimental class was more significant than in the control class.

Based on the results of descriptive analysis, it shows the increase in scores on the pretest and posttest of the experimental class and control class is seen in the table below.

Table 1. Data distribution of learner learning outcome scores.

N	Experimental Class			Control Class		
	Pretest	*Posttest*	*N-Gain*	*Pretest*	*Posttest*	*N-Gain*
32	25.16	84.83	0.79	15.48	50	0.39

Based on the table above, it can be obtained that the experimental class has a value with a high category and the control class has a medium category. This is because differentiated learning with the

discovery learning model is effective in improving students' learning outcomes compared to conventional methods. [9] learners who learn with discovery learning show higher improvements in concept understanding, critical thinking skills, and problem-solving abilities compared to learners who learn using the discovery learning method with learning styles. Discovery-based learning helps learners with different learning styles to achieve optimal results, as they can customize the approach that best suits the way they absorb information.

Specifically, the analysis of pretest and posttest scores can be seen at each level of learner ability. Based on the results of the analysis of pretest and posttest scores, there is a significant difference in the learning outcomes of students before and after being given treatment in the experimental class and control class in Newton's Law material. Before being given treatment, the pretest score in the control class showed that most students were in the low category with an average score of 15.48, while the experimental class had an average score of 25.16. After being given treatment, the experimental class posttest score increased to 84.83 with a high category with the calculation of the N-Gain Score showing that the experimental class had a value of 0.79 (high category), while the control class only reached 50 in the moderate category with the calculation of the N-Gain Score the control class only reached 0.39 (moderate category). These results are in line with previous research, which shows that experimental methods are more effective in improving students' cognitive learning outcomes than conventional methods[10]. Research [11] also supports that experimental methods are more effective than conventional methods in improving students' understanding. In this research, learners are divided into group based on indicators of learning outcomes of cognitive abilities from each aspect, from the ability to remember to the ability to create. Meanwhile, the table of learning outcome indicators is shown in the figure 1.

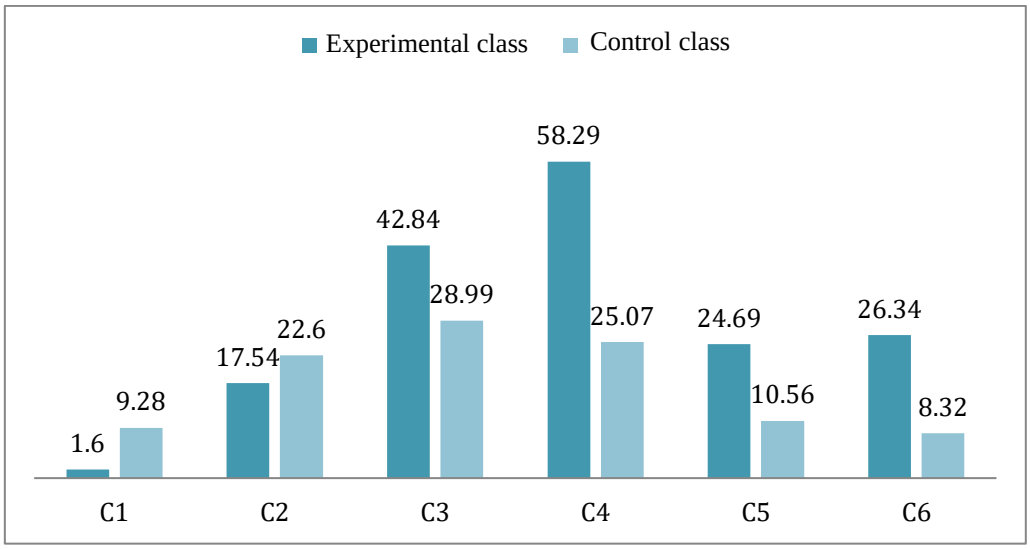

Figure 1. Data on the average difference score based on indicators

The increase in student learning outcomes is not only seen from the total score, but also from each question indicator in the cognitive dimension. In the experimental class, the highest increase occurred at the analysis level (C4) with an increase in the pretest value of 5.44. This is because learning with the discovery learning model encourages students to analyse and evaluate information independently. This finding is supported by the results of research in Saudi Arabia, which shows that the use of guided discovery and scaffolding strategies significantly improves higher-order thinking skills[12]. In addition, on the indicator of creating (C6), learners were in the moderate category, with 58.40% of them able to choose and write answers correctly, as supported by research [13].

In the experimental class, the smallest increase occurred at the low cognitive level (C1) with an increase of 1.6, from the pretest score of 18.24. Learners already understand the questions at the cognitive level (C1) , with the ability to remember. One of the causes is that students already have a

high ability to question at this level [14]. This finding also found that although there was an increase in learning outcomes at the C1 level after treatment, the increase was not significant because students already had knowledge from the beginning. Meanwhile, the study [15] also showed that posttest scores at the C1 level were higher in the experimental class than in the control class, indicating that learners already understood the basic concepts from the beginning.

In the control class, the highest increase occurred at the application level (C3) with an increase of 28.99, from the pretest score of 12.5 to 41.49 in the posttest. This is because in the control class, the teacher gave more examples of problems to students using Newton's Law. This also shows that the cognitive ability of students at the application level (C3) in solving Newton's Law problems has a percentage of 60%, which indicates that many students can apply concepts after being given examples of appropriate problems[16].

Meanwhile, the smallest increase in the control class occurred at the level of creating (C6) with an increase of only 8.32 points, from the pretest average score of 1.6. This suggests that the learning method used is less effective in helping learners understand, apply, and analyse material that requires higher-order thinking skills. Research [17] reveals that without appropriate learning strategies, students have difficulty in solving problems that require analytical, evaluative, and creative thinking skills. This finding is consistent with Bruner's theory, which emphasises that discovery-based learning helps learners more easily understand concepts before applying them.

In addition, the results showed that the implementation of differentiated learning with a discovery learning model led to a more significant increase in learning outcomes in the experimental class compared to the control class, with a significance value of 0.000 <0.05. This is reinforced by the research of Muslim et al. (2023), which stated that the use of differentiated discovery models significantly improved concept understanding and process skills.

This finding is supported by research[18] , which shows that the use of various learning styles, such as visual, audio, and kinesthetic, can significantly improve concept understanding. By understanding the learning styles of students, educators can develop learning strategies that are more effective and support the optimal development of each individual in the classroom [19].

In this study, experimental class learners were grouped based on their learning styles, with the majority having audio (20 students), visual (7 students), and kinesthetic (4 students) learning styles. This approach is in line with research showing that grouping based on learning styles increases learning effectiveness [20]. Meanwhile, research [21] confirms that differentiated learning tailored to individual learning styles can improve learners' understanding.

From the data obtained, learners are grouped with visual, audio, and kinesthetic learners in one group. By combining various methods and strategies in one lesson, teachers can ensure that all students with visual, audio, and kinesthetic learning styles can understand the material optimally. Each student has a unique way of learning, so a varied approach will help them to absorb information more effectively. If learning is only focused on one learning style, then students with different learning styles may have difficulty understanding the concepts taught. Therefore, it is important for teachers to design strategies that include various approaches so that all students can be actively involved in the learning process.

The effectiveness of the implementation of differentiated learning with the discovery learning model was also analysed using Cohen's d Effect Size value, which showed an effectiveness of 1.05 and fell into the high category. This result is in line with the research [22], which shows that differentiated learning with discovery learning model has an effect size value of 1.05, which is also categorised as high. Based on Cohen's criteria, this value shows a significant impact on improving student learning outcomes.

Thus, the implementation of differentiated learning with the discovery learning model is proven to be more effective in improving learning outcomes than the expository method. This combination of methods helps learners understand the material more deeply with an approach that suits their learning style. Research [23] supports that differentiated learning combined with discovery learning can significantly improve learning outcomes. Therefore, this approach can be a recommended strategy for educators in improving the quality of learning in the classroom.

4. Conclusion

Based on the results of data analysis and discussion, it can be concluded that the implementation of differentiated learning with the discovery learning model is effective in improving students' learning outcomes on Newton's Law material at Kemala Bhayangkari 1 Kubu Raya High School. This is indicated by an increase in the score of learning outcomes from the low to high category in the experimental class, as well as a significant difference between the experimental and control classes based on the independent sample t-test with a significance value of 0.000 (<0.05), so Ha is accepted and Ho is rejected (there is an increase in learning outcomes after the implementation of differentiated learning discovery learning model). In addition, the effect size value of 2.042 indicates that the effectiveness of the applied learning model is in the high category. Thus, the implementation of differentiated learning based on discovery learning is proven to be able to significantly improve student learning outcomes.

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