

Implementation of Differentiated Project-Based Learning Model in Physics Education: A Study on the Law of Conservation of Mechanical Energy at MAN 1 Bone

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ABSTRACT

This study aims to analyze the effect of implementing a differentiated Project-Based Learning (PjBL) model on student learning outcomes. This study employs a one-group pretest-posttest design, conducted at MAN 1 Bone. The subjects of this study were students of MAN 1 Bone class X2 who were selected using random sampling. Learning outcome data were obtained from pretest and posttest written tests. The data were analyzed using descriptive statistics and hypothesis testing, employing the t-test (with the aid of SPSS). The results of the analysis showed a significant increase from the average pretest score (49.6) to the average posttest score (74.74). The t-test results showed significance ($p < 0.05$). Thus, the application of differentiated PjBL proved to be effective in improving student learning outcomes.

Keywords: *Differentiated Project-Based Learning, Learning Outcomes, Law of Conservation of Mechanical Energy, Physics Learning.*

1) INTRODUCTION

Physics education, which is a branch of science, usually faces challenges in achieving optimal learning outcomes. This is especially true for materials that require a deep conceptual understanding. One of the materials highlighted in this study is the Law of Conservation of Mechanical Energy, which is an important concept in physics but is still often difficult for students to understand. The difficulties experienced by students stem not only from the complexity of the concept, but also from the teaching methods often used in schools, which tend to involve students less actively in the learning process.

An interview with a physics teacher at MAN 1 Bone showed that student performance in class was poor. Midterm exam results showed that a large number of students had not met the minimum passing grade. Although various learning models had been implemented, the interviewee emphasized that teachers remained the dominant figure. As a result, students simply sat in class without understanding the material.

The learning approach chosen for students has an impact on their level of mastery and achievement. One learning model that encourages students to participate actively is Project Based Learning (PjBL). Through the use of projects, students are encouraged to be active in learning and to use their creativity and skills (Setyo Adj Wahyudi et al., 2023). Students need to be involved in the learning process so that they can achieve their academic goals, and this requires support from teachers in guiding students to give their full attention to learning (Fathurrohman, 2015). The use of effective learning models will maximize the results of learning objectives. There is a growing perception that conventional learning is inadequate in today's modern classrooms and that learner-centered learning is a viable alternative. This is due to the fact that conventional education places teacher-centered learning at the forefront.

PjBL is a learning approach that involves students in authentic learning experiences that are relevant to the world of work. PjBL supports the development of technical skills and understanding as well as professional competencies and identity. The integration of technical and professional competencies in authentic PjBL learning experiences, where students work on real technical problems, provides opportunities to engage with the complexities of practice and how to apply knowledge in practice (Miao et al., 2024) .

Project-based learning (PjBL) provides students with authentic, engaging, and complex problems that they must design solutions or artifacts for based on data collection, assumptions, and further questions. Students apply and integrate concepts and procedures while improving their professional skills. We will also refer to problem-based learning (PBL), which aims to learn concepts and procedures through well-chosen authentic situations. (MacLeod & van der Veen, 2020) .

Amidst the diversity of students, there needs to be a learning approach that can be tailored to the interests and abilities of students. Differentiated learning is an idea that emphasizes that learning approaches must be diverse and tailored to meet the individual needs of each student. There are three components that must be considered in differentiated learning: content differentiation, process differentiation, and product differentiation. These three elements are tailored based on the interests and abilities of students (Setyo Adj Wahyudi et al., 2023).

To determine whether students understand the lesson, it is necessary to conduct a learning assessment test. Learning outcomes show students' ability to accept, reject, and evaluate the knowledge acquired during the learning process. An individual's learning outcomes indicate their proficiency in understanding the subject, which is usually evidenced by their grades after the education process. Good results can be determined after assessment. These evaluation findings can show the extent of individual achievement. (Fadly, Rafiqah, 2018).

2) METHODS

The research design was a one-group pretest-posttest experimental design. The research subjects were 35 students in class X Unggulan 2 at MAN 1 Bone. The learning process emphasized differentiated project-based learning to improve students' learning outcomes in understanding the concept of the Law of Conservation of Mechanical Energy. Participants actively designed and implemented projects according to their interests and ability levels. Learning outcomes were assessed based on pretest and posttest scores and analyzed according to the students' ability to apply the concept of the law of conservation of mechanical energy conceptually and procedurally during the project process.

The instruments used in this study were pre- and post-treatment learning outcome tests. The data obtained were cognitive test scores to measure students' understanding of the concept of the Law of Conservation of Mechanical Energy. The data obtained were then categorized based on the scores obtained using the table presented by (Arikunto, 2011) and then analyzed using descriptive statistics and hypothesis testing with a paired sample t-test.

The categorization of learning outcomes is adopted from (Arikunto, 2011) as shown in Table 1.

Table 1: *Categorization of Students' Cognitive Learning Outcomes*

Score	Categorization
80 - 100	Veri Good
60 - 79	Good
40 - 59	Fair

20 - 39 Poor

0 - 19 Failing

3) RESULTS AND DISCUSSION

Based on the results of the research that has been conducted, there are differences between students before learning using the differentiated PjBL learning model and after using the differentiated PjBL learning model. For more details, see Table 2 below.

Tabel 2: *Paired Samples Statistics*

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	learning outcomes before treatment	49,6000	35	1,78556	,30182
	learning outcomes after treatment	74,7429	35	1,86836	,31581

Based on the analysis results, the pre-test average score was 49.6 and the post-test average score was 74.7429. This shows that there was a difference in learning outcomes before and after the treatment in terms of the average scores of the students.

Tabel 3: *Paired Samples Test*

Paired Samples Test									
	Paired Differences				t	df	Significance		
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			One-Sided p	Two-Sided p	
				Lower					Upper

Pa ir 1	learnin g outcom es before treatme nt - learnin g outcom es after treatme nt	- 25,142 86	,69209,116 98	- 25,380 60	- 24,905 12	- 214,9 24	3 4	<,0 01	<,0 01
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Based on the results of Table 3 analysis, it is known that there is a difference between the pre-test and post-test averages of 25.14286. The sig. value is <0.001, so it is stated that the sig. value is < 0.05. It is concluded that there is a significant difference between the learning outcomes of students in the pre-test and post-test data.

Based on the results of the analysis of the data before and after, the difference in student learning outcomes before and after teaching can be seen in the following diagram:

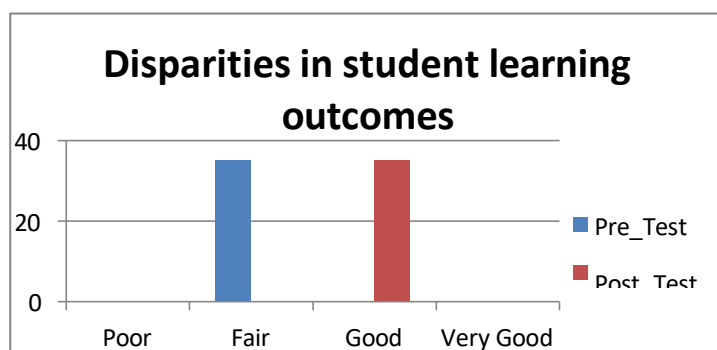


Figure 1: *Pre-Test and Post-Test Scores of Students' Learning Outcomes*

He results showed that there was a difference in student learning outcomes before and after being taught using the differentiated Project Based Learning (PjBL) model. This can be seen from the difference in the maximum and minimum scores as well as the average scores obtained in the pre- test and post-test. To prove this, data analysis was carried out using IBM SPSS v.30 software.

From the analysis results, data on the hypothesis test results were obtained using the Paired Sample T-Test based on calculations performed with the help of IBM SPSS version 30. Based on the analysis output, the average learning outcome before treatment was 49.60 and the average learning outcome after treatment was 74.74. Furthermore, based on the T-test results shown in the analysis table, the t-count value was -214.924 with a significance value (sig.) of less than 0.001 ($p < 0.05$). This indicates that the t-count is greater than the critical value (sig. value $< \alpha = 0.05$), so the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted.

Thus, it can be concluded that there is a significant difference between students' learning outcomes before and after the implementation of the differentiated Project Based Learning (PjBL) model on the subject of the Law of Conservation of Mechanical Energy. This difference shows that the implementation of this learning model is able to improve student learning outcomes. The graph comparing pre-test and post-test learning outcomes further illustrates a significant improvement after the learning treatment was given.

4) CONCLUSIONS

There was a difference in student learning outcomes before and after being taught using a differentiated Project Based Learning (PjBL) model, as indicated by an average increase of 25.14. This was based on the average learning outcome score before the treatment of 49.60 and after the treatment of 74.74. Furthermore, based on the results of hypothesis testing using the Paired Sample T-Test analyzed with IBM SPSS version 30, a t-value of -214.924 was obtained with a significance value (sig.) of less than 0.001 ($p < 0.05$). These results indicate a significant difference between the learning outcomes of students before and after the application of the differentiated Project-Based Learning (PjBL) model on the subject of the Law of Conservation of Mechanical Energy.

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