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ARTICLE

Learning circular motion with the demonstration method using the problem-based learning model to improve physics learning outcomes

Lumenia Az-zahra[*,1] and Ali Ismail[2]

[1]SMK PGRI Garut, Indonesia
[2]Department of elementary teacher education, Universitas Pendidikan Indonesia, Indonesia
[*]Corresponding author. Email: lumeniaazzahra2807@gmail.com

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Abstract

This study aims to improve students' learning outcomes on the topic of circular motion through the application of the demonstration method using the Problem-Based Learning (PBL) model. The research was conducted at a public high school in Garut. The research method used was an experimental approach with a Pretest-Post test Control Group design. The sample was selected using purposive sampling, consisting of one experimental class that applied the demonstration method with the PBL model and one control class that used conventional methods. The instrument used was an essay test comprising six questions. The results showed that the demonstration method with the PBL model led to a significant improvement in students' learning outcomes compared to conventional methods. The average pretest score of the experimental class increased from 26.34 to 70.51 in the post-test, while the control class increased from 26.54 to 58.54. Based on the t-test results, the implementation of the demonstration method with PBL was more effective in enhancing students' learning outcomes on the topic of circular motion.

Keywords: Problem-Based Learning (PBL), demonstration, learning outcomes, circular motion

1. Introduction

Education is a teaching and learning process aimed at helping individuals acquire the knowledge, skills, values, and attitudes necessary to become productive members of society. Education is the most important means for the progress of a nation and a country, as it is a cultural process that enhances human dignity and worth (Abdurahman et al. 2023). Education can take place in various ways, such as through schools, universities, job training, or self-directed learning. It plays a crucial role in shaping character and preparing individuals for the future. Through education, individuals can acquire the knowledge and skills needed to work and contribute to society. The goal of education is to produce individuals with academic abilities, social skills, creativity, critical and logical thinking, and strong moral values. Furthermore, education plays a vital role in shaping individual character and personality, as well as helping individuals face changes and challenges in life. Learning can take various forms, including formal education such as schooling and higher education, job training, or even self-learning through reading books, watching videos, or taking online courses.

One of the challenges in learning is the low absorption capacity of students. Physics is one of the subjects taught at the high school level. It is a branch of science that studies the fundamental nature of the universe, including matter, energy, and their interactions. Physics covers various disciplines such as mechanics, thermodynamics, electromagnetism, optics, and modern physics, including quantum physics, relativity, and cosmology. Physics plays a crucial role in human understanding of the world and facilitates the development of new technologies and innovations. However, physics learning is often perceived as difficult and uninteresting. Many students consider physics a challenging subject that is hard to understand and even fear it. In reality, physics is not as difficult as students imagine if it is taught using appropriate and effective methods (Evendi and Verawati 2021).

Circular motion is a common phenomenon in daily life, such as the motion of objects rotating around a center, including wheels, planets orbiting the sun, or electric fans. Although this concept is frequently encountered, it is often difficult for students to grasp due to its mathematical calculations and complex physical visualizations. Circular motion involves several key concepts, such as angular velocity, centripetal acceleration, centripetal force, period, and frequency. Understanding these concepts is crucial as it influences students' ability to comprehend more advanced physics topics. In many cases, the teaching methods used by physics teachers still predominantly rely on conventional approaches, such as lectures and question-and-answer sessions. The lecture method tends to be passive, where students merely receive information without actively participating in the learning process. This results in low student engagement and a lack of deep understanding of the material being taught.

This study aims to examine the effectiveness of combining the demonstration method with the PBL model in improving students' learning outcomes on the topic of circular motion in tenth-grade high school students. This approach is expected to serve as an effective alternative for physics teachers in delivering more interactive and engaging lessons to students.

2. Literature Framework

2.1 Problem Based Learning (PBL)

Problem-Based Learning (PBL) is a learning model that focuses on solving real-world problems relevant to students' lives. PBL emphasizes the development of critical thinking skills, collaboration skills, and the ability to find creative solutions to problems. According to Sanjaya (Jaenudin, Murwaningsih, et al. 2017), the PBL model has several advantages, namely:

1. Enhancing critical thinking skills – Students are taught to view problems from multiple perspectives, analyze data, and make decisions based on available information. This improves their critical thinking abilities.
2. Improving social skills – PBL teaches students to work collaboratively in groups, communicate effectively, and solve problems together, thereby enhancing their social skills.
3. Increasing learning motivation – PBL engages students more in the learning process, as they are required to complete tasks and solve real-world problems, which boosts their motivation to learn.
4. Relevance – Students study problems that are directly related to their lives, making them more engaged and helping them see the real-world significance of their learning.
5. Developing practical skills – Students learn to solve real problems, allowing them to develop useful practical skills for their daily lives.
6. Enhancing understanding – PBL enables students to learn more deeply, as they must actively solve problems and complete meaningful tasks, thereby improving their comprehension of the subject matter.

In the context of physics learning, PBL provides students with opportunities to connect physics concepts to real-world phenomena around them. For example, in the topic of circular motion, students can be given problems such as how to measure angular velocity and centripetal acceleration on a bicycle wheel. In this way, students can understand abstract physics concepts through direct and relevant experiences (Kawuri, Ishafit, and Fayanto 2019; Khoiriyah and Husamah 2018).

2.2 Demonstration approach

The demonstration method is a teaching technique that involves using visual aids to show how a concept or principle works. In physics learning, this method is highly beneficial as it allows students to directly observe how physical laws apply in real-world situations. For example, by demonstrating circular motion using a fan or a wheel, students can directly see how angular velocity and centripetal force operate. The demonstration method is highly effective (Maričić, Cvjetićanin, and Anđić 2019) because it enables students to:

1. Better understand concepts – Students can see firsthand how something is done or operates, allowing them to grasp concepts more effectively than through reading or listening to a teacher's explanation alone.
2. Stimulate curiosity – Seeing real-life examples can spark students' curiosity about the topic being discussed, motivating them to learn more and actively participate in the learning process.
3. Develop practical skills – Students can develop hands-on skills and become familiar with proper methods for performing actions or using tools.
4. Engage with the material – Direct interaction with the subject matter helps students gain a deeper understanding and creates a more enjoyable learning experience.
5. Make learning more engaging – By seeing and experiencing concepts firsthand, students find lessons more interesting and interactive, leading to greater involvement and increased motivation to learn.
6. Enhance memory retention – The visual and hands-on experiences provided by the demonstration method help students retain information more effectively and for a longer period, as they can connect real experiences with the knowledge conveyed by the teacher.

The combination of the demonstration method with the Problem-Based Learning (PBL) model is believed to provide a more profound learning experience. Students not only observe how physics concepts are applied but also gain the opportunity to solve problems related to the phenomena they witness (Sever, Oguz-Unver, and Yurumezoglu 2013).

2.3 Learning outcomes in physics

Learning outcomes measure how well students understand the material that has been taught. According to Bloom's revised taxonomy, learning outcomes can be categorized into three main domains: cognitive, affective, and psychomotor. The cognitive domain relates to intellectual abilities, such as remembering, understanding, applying, analyzing, evaluating, and creating. The affective domain involves emotions, attitudes, and values, assessed based on how well students respond to and evaluate the given information. The psychomotor domain refers to students' physical abilities in performing motor activities, such as conducting physics experiments. In this study, learning outcomes were measured using pretest and posttest assessments to determine the extent of students' understanding improvement after being taught using the demonstration method with the Problem-Based Learning (PBL) model.

3. Research Method

3.1 Research design and participants

This study employs a Pretest-Post test Control Group design, consisting of two groups: the experimental group and the control group. The experimental group receives treatment in the form of learning through the demonstration method combined with the Problem-Based Learning (PBL) model, while the control group is taught using conventional methods (lectures and question-and-answer sessions). This design allows the researcher to measure students' learning improvement in both groups before and after the treatment. A pretest is conducted before the learning process begins to assess students' initial understanding, and a post-test is administered after the learning process to evaluate their improvement.

The population for this study consists of tenth-grade science students from seven different classes. The sample includes 35 students in the control class and 35 students in the experimental class. The sampling method follows the Non-Equivalent Group Design, which involves conducting a pretest before administering the treatment to both the experimental and control classes. After receiving the treatment, both groups are given a post-test to measure their learning outcomes.

3.2 Research instruments

The instrument used to collect data in the pretest is typically used again in the posttest. This test consists of six essay questions focusing on the topic of circular motion. The questions are based on the cognitive domain, ranging from C1 to C4 levels. This instrument is useful for measuring students' cognitive abilities before and after the treatment in both the experimental and control classes. Before conducting the study, the researcher first conducted a trial of the test items at the same school and grade level, involving 35 students. After completing the trial data collection, the researcher performed an analysis to assess validity, reliability, discrimination index, and difficulty level of the test items.

3.3 Data analysis

The collected data was analyzed using the t-test statistical analysis to determine whether there was a significant difference between the pretest and posttest results in the experimental and control groups. Additionally, the N-Gain test was used to measure the effectiveness of the learning process by calculating the improvement in students' learning outcomes. This data analysis was conducted using SPSS version 16.0. The data analysis techniques are as follows:

In the initial stage of data analysis, the researcher performed a normality test using the Kolmogorov-Smirnov technique. This test was chosen to facilitate accurate decision-making, considering the sample size of 70 students, with 35 students in each class. The normality test was conducted using the Kolmogorov-Smirnov method, with the decision criteria as follows: if the significance probability (Sig.) value is greater than 0.05, the data distribution is normal; if the Sig. value is less than 0.05, the data distribution is not normal. The normality test was conducted using the Kolmogorov-Smirnov test in IBM SPSS Statistics Version 29.

Then, hypothesis testing in this study was conducted using the Independent Sample t-Test, which compares two different samples. This test was used to determine whether there was a significant difference in the average scores of two independent samples. The Independent Sample t-Test is only applicable when the data is normally distributed. This technique allowed for the comparison of pretest and posttest results between the experimental and control classes. The Independent Sample t-Test follows the Equal Variances Assumed criteria. If the t-test significance value is less than 0.05, the hypothesis is accepted, meaning there is a significant difference in learning outcomes between the experimental and control classes. Meanwhile, if the t-test significance value is greater than 0.05, the hypothesis is rejected, meaning there is no significant difference in learning outcomes between the two classes.

To assess the effectiveness of the applied treatment in the learning process for improving students' learning outcomes, the N-Gain test was used (Guantara, 2021). The N-Gain test measures the improvement in pretest and post-test scores by calculating the Average Normalized Gain. The N-Gain calculation follows the formula introduced by Hake.

4. Result of the research

Based on the data analysis results, there was a significant improvement in students' learning outcomes in the experimental class compared to the control class. The following are the pretest and posttest data analysis results for both groups. The average pretest score in the experimental class was 26.34, while in the control class, it was 26.54. Meanwhile, the average posttest score in the experimental class increased to 70.51, whereas in the control class, it increased to 58.54. These results present the data analysis findings for both the pretest and posttest in the experimental class (which received the demonstration method combined with PBL) and the control class (which received the lecture method).

Based on the data in the table, it can be proven that the average pretest score for the experimental class was 26.34. After receiving treatment to improve learning outcomes using the demonstration method and the PBL model, the average posttest score increased to 70.51. Meanwhile, in the control class, the average pretest score was 26.54, and after receiving treatment using the conventional teaching method, the average posttest score increased to 58.54. Based on the analysis of the pretest and posttest data in both the experimental and control classes, it can be concluded that there was a significant improvement in learning outcomes in the experimental class. Therefore, it is suggested that the teaching method used in the experimental class, which combines the demonstration method and PBL model, has a more significant positive impact compared to the conventional method used in the control class.

Table 1. Descriptive statistics

Measurement	Experimental group			
	Pretest	Posttest	Pretest	Posttest
Number of students	35	35	35	35
Minimum score	10	50	10	42
Maximum score	42	83	33	75
Mean	26,34	70,51	26,54	58,54

A normality test was conducted on two sets of data: the pretest and posttest results for both the experimental and control groups. This normality test used the Kolmogorov-Smirnov technique, which aims to determine whether the collected data is normally distributed. According to the criteria, the data is considered normally distributed if Sig. > 0.05. The normality test analysis was conducted using IBM SPSS Statistics Version 29.0.

The results of the normality test for the experimental class are as follows: Pretest (Statistic = 0.134, df = 35, Sig. = 0.118), and Posttest (Statistic = 0.128, df = 35, Sig. = 0.155). Based on these normality test results, since the Sig. value for all data (experimental and control classes, both pretest and posttest) is greater than 0.05, it can be concluded that the sample comes from a normally distributed population. Based on the results of the normality test, the students' learning outcomes for all data, including the experimental and control classes, showed the following results: Pretest (Statistic = 0.143, df = 35, Sig. = 0.066), and Posttest (Statistic = 0.142, df = 35, Sig. = 0.073). Since the Sig. value is greater than 0.05, it can be concluded that the sample comes from a normally distributed population. Furthermore, because the research data is normally distributed and consists of two independent groups, the researcher can use a parametric statistical test, specifically the Independent Sample t-Test.

If the research data is normally distributed and has homogeneous variance, hypothesis testing can be conducted. The hypothesis test used in this study is the Independent Sample t-Test, which is designed to determine whether there is a significant difference in the mean scores of two independent samples. This test was applied to the posttest data from the experimental class (demonstration method and PBL model) and the control class (lecture method). The Independent Sample t-Test is used to evaluate the research hypothesis. Based on the data analysis in Table 4.7, the significance value from

Table 2. Result of normality test

Group	Kolmogorov-Smirnov			Conclusion
	Statistic	df	Sig.	
Pretest control group	0,143	35	0,066	Normal
Posttest control group	0,142	35	0,073	Normal

Levene's Test for Equality of Variances was 0.265. Since 0.265 > 0.05, it can be concluded that the variance between the experimental and control classes is homogeneous.

According to the Independent Sample t-Test table, the significance value Sig. (2-tailed) was 0.002. Since 0.002 < 0.05, it can be concluded that Ha is accepted, and H0 is rejected. Therefore, there is a significant difference in the average improvement of students' learning outcomes between the experimental class (which used the demonstration method and PBL model) and the control class (which used the lecture method).

Table 3. Result of hypothesis

Measurement	Levene's Test for Equality of Variances				
	Sig.	T	df	Sig. (2-tailed)	Mean Difference
Equal variances assumed	0.265	3.245	68	0.002	7.114
Equal variances not assumed		3.24	65.93	0.002	7.114

Furthermore, the table shows that the Mean Difference is 7.114, indicating the difference in the average learning outcomes between the experimental and control classes. To further clarify the posttest averages, the posttest score for the experimental class (demonstration method and PBL model) was 66.26, while the posttest score for the control class (conventional method) was 59.14. Thus, it can be concluded that students' learning outcomes were higher when using the demonstration method and PBL model compared to the conventional method.

The purpose of the Normalized Gain (N-Gain) test is to determine the effectiveness of learning improvement in both the experimental and control classes. The N-Gain score is the difference between the posttest and pretest scores. The average N-Gain score for the experimental class (which used the demonstration method and PBL model) was 0.59, categorized as a moderate improvement, with an N-Gain percentage of 59%, meaning it is considered moderately effective. The average N-Gain score for the control class (which used the conventional method) was 0.43, also categorized as a moderate improvement, but with an N-Gain percentage of 43%, meaning it is considered less effective.

5. Discussion and conclusion

The results of this study indicate that the combination of the demonstration method with the Problem-Based Learning (PBL) model is more effective in improving students' learning outcomes on circular motion compared to using the lecture technique. The demonstration method helps students understand abstract concepts such as angular velocity, centripetal acceleration, and centripetal force through visual and hands-on experiences. By observing demonstrations of circular motion, students can connect theoretical concepts with real-world applications (Watson and West 1996; Preeti, Ashish, and Shriram 2013).

On the other hand, the PBL model encourages students to think critically and solve problems collaboratively. When students are presented with real-life problems relevant to their experiences, they become more motivated to learn and better understand the physics concepts being taught. This study aligns with previous research, which has shown that the PBL model is effective in enhancing students' critical thinking skills and conceptual understanding. Bahar (2019) found that combining the demonstration method with PBL helps students grasp physics concepts more effectively, as they do not simply memorize information but actively engage in the learning process.

From the findings of this study, it can be concluded that the use of the demonstration method combined with the PBL model is effective in improving students' learning outcomes in circular motion. This method provides a more interactive learning experience, making it easier for students to grasp abstract physics concepts. Physics teachers are encouraged to adopt this teaching approach as an alternative to presenting material in a way that is more engaging and relevant for students (Preeti, Ashish, and Shriram 2013; Permatasari et al. 2019).

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