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The Effect of Problem-Based Learning Models on Students' Understanding of Physics Concepts at Senior High School

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Abstrack – Students' understanding of physics concepts is an important skill in 21st century education. But the real condition in school still many students were not understand physics concepts, so it need to use innovation learning models, one of them is problem-based learning models. The research aims are: to find alternative ways for high school students to understand physics concepts; and to find out wether there is an effect of problem-based learning models on students' understanding of physics concepts at senior high school. This research type is pre-experimental designs with the Intact-group comparison model. The population was students at XI science of SMA Negeri 2 Mataram in the 2024/2025 Academic Year, it consisting of 8 classes. The sample was selected using a purposive sampling technique. Students at XI science 5 as the experimental class and students at XI science 8 as the control class. The Experimental class treated used a problem-based learning model in learning, while the control class used a direct learning model. The results of data analysis showed that the average value of conceptual understanding in static fluid material for the experimental class was 74 and for the control class was 63. These data were analyzed using parametric statistical tests, namely the polled variance t-test. The results of the hypothesis test showed that the t_{count} are 2,4866 and the t_{tables} are 1,9989, it can be concluded that there is an effect of the problem-based learning model on students' understanding of physics concepts at high school.

Keywords— problem-based learning; physics concept understanding; intact-group comparison.
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1. Introduction

Physics is one of the branches of natural science which is a science of natural phenomena that is poured in the form of facts, concepts, principles and laws that have been tested for truth through a series of activities in the scientific method [1]. Physical science is very close to human life because it discusses natural phenomena or events that occur in everyday life. Some examples are that humans always move, feel heat, cold and so on. These phenomena are brought into physics learning activities.

Physics learning is a teaching and learning process that involves teachers, students, and the environment about natural phenomena that are poured in the form of facts, concepts, principles, and laws that are tested for truth through a series of activities in the scientific method. In learning physics there are various components that are interconnected with one another. These components include learning objectives, materials, methods and evaluation [2].

There are several demands of 21st century education, including that students must have skills in the cognitive domain (problem solving, critical thinking, and systematic thinking), interpersonal (complex communication, sociability, cooperation, cultural sensitivity, and ability to deal with differences), and intrapersonal (self management, self-development, time management, self-regulation, adaptability, executive functioning) [3]. To realize this, participants must understand the concepts and applications of each material studied. However, in reality at school, there are still students who do not understand the concept of the material being studied and there are still many who do not understand the concept.

There are 51% of students who say that physics is difficult to understand, including saying because physics is too many formulas, many concepts and some of them convey because the teacher is too fast in explaining and boring learning methods. Finally, students have no interest in learning physics and tend to be passive in learning activities [4]. One of the problems of education today is caused by quite a number of teachers who apply teacher-oriented learning models so that students do not have the opportunity to discover for themselves the physics concepts they learn [5].

Based on the results of observations at SMA Negeri 2 Mataram by conducting interviews with physics teachers in class XI science in the 2024/2025 school year, there are still many students who do not understand the concept of physics material taught and tend to be passive in learning activities. This can be seen from the summative assessment scores of students in the class and from daily learning activities. The average value of the summative assessment results of class XI science students at SMA Negeri 2 Mataram can be seen in Table 1.

Table 1. Average Score Summative Assesement Result

No.	Class	Average Score
1.	XI Science 1	76, 71
2.	XI Science 2	62, 64
3.	XI Science 3	61, 94
4.	XI Science 4	62, 94
5.	XI Science 5	73, 47
6.	XI Science 6	51, 94
7.	XI Science 7	66, 81
8.	XI Science 8	66, 29

This condition still occurs even though the teacher at school has tried to use a variety of learning models in learning, with the hope of attracting students to learn actively and try more to understand the concept of the material being taught. One of the learning models that is expected to increase the curiosity of students so that it will increase their activity in learning activities and make them able to understand the concept of the material being studied better is the problem-based learning model. The use of problem-based learning models will make students motivated to learn and be actively involved in learning activities [6]. This model is a learning model that makes problems as a basis for students to learn. By using this model, learning begins by posing a problem, question, or puzzle that makes students want to learn to solve it [7]. Thus, the researcher intends to conduct research on the Effect of Problem-Based Learning Models on Student's Understanding of Physics Concepts at Senior High School.

2. Research Methods

This type of research is a pre-experimental design with an intact-group comparison model. This design mean that researchers used 2 classes of students who became experimental and control classes. The two classes were not given an initial test, but their initial abilities were seen from the summative assessment results they had carried out in the even semester of the 2024/2025 school year. After that, treatment was given using a problem-based learning model in the experimental class while the control class was given treatment using a direct learning model. After that, a test of students' concept understanding in the class is carried out according to the material that has been given, namely static fluid material.

2.1 Populations and samples

The population in this study were students of SMA Negeri 2 Mataram class XI science. The sampling technique that researchers use in this study is purposive sampling, which is a technique used by researchers if the researcher has certain considerations in sampling [8]. The research sample was SMA Negeri 2 Mataram students in class XI science 5 as many as 32 students as the experimental class and class XI science 8 as many as 32 students as the control class.

2.2 Instruments

The instrument used in this study is a concept understanding test instrument in the form of multiple choice questions totaling 15 questions. Data collection techniques using the test method.

2.3 Data and Analysis

The research data were analyzed using the prerequisite analysis test in the form of homogeneity test and normality test. If the data is homogeneous and normally distributed, the hypothesis test is carried out using a parametric test, namely the polled variance t-test.

3. Result and Dicussion

3.1 Results

3.1.1 Instrument Test

Before the research was conducted, the instrument test was carried out first to determine the feasibility level of the instrument to be used. The research instrument that was tested was in the form of a concept understanding test question in the form of multiple choice as many as 20 questions but 15 questions were used in the study. The questions have been tested on students of class XI science 1 at SMA Negeri 2 Mataram with a total of 31 students. The instrument test includes validity test, homogeneity test, test the level of difficulty of the question, test the differentiation test of the question and test the exception. From testing the questions, 7 valid questions and 8 invalid questions were obtained, can be seen in table 2. All questions are reliable, can be seen in table 3.

Table 2. Results of the Problem Validity Test

Number of Questions	Criteria	Category
7	$r_{xy\geq}r_{table}$	Valid
8	$r_{xy<}r_{table}$	Not Valid

There is 1 difficult question, 2 medium questions and 12 other questions categorized as easy, can be seen in table 4. For the test of the differential power of the questions, there are 7 questions with the category of poor differential power, 3 questions with sufficient differential power, 4 questions that have good differential power and there is 1 question with very good differential power, can be seen in table 5. The last test is the checker test, based on the tests that have been carried out, there are 7 questions whose checker power is very bad, 5 questions whose checker power is bad and 3 questions whose checker power is sufficient.

Table 3. Reliability Test Results

Number of Questions	Value Range	Category
15	$r_{11} \geq r_{table}$	Reliable
0	$r_{11} < r_{table}$	Not Reliable

Table 4. Problem Difficulty Test Results

Number of Questions	Value Range (VR)	Category
1	$VR \leq 0{,}3$	Difficult
2	$0{,}3 \leq VR \leq 0{,}7$	Moderate
12	$VR \geq 0{,}7$	Easy

Table 5. Differential Test Results

Number of Questions	Differential (D)	Category
0	$D < 0$	Very Bad
7	$0 \leq D < 0{,}20$	Bad
3	$0{,}20 \leq D < 0{,}40$	Enough
4	$0{,}40 \leq D < 0{,}7$	Good
1	$0{,}7 \leq D \leq 1$	VeryGood

Table 6. Results of the Exposure Effectiveness Test

Number of Questions	Option Selected > 5%	Category
0	4 option	Very Good
0	3 option	Good
3	2 option	Enough
5	1 option	Bad
7	0 option	Very Bad

3.1.2 Summative Assessment Data Analysis

Based on the summative assessment results from the school, the researcher conducted a homogeneity test so that it could determine whether the two classes could be used as research samples or not. The summative assessment results of the experimental and control classes can be seen in Fig. 1.

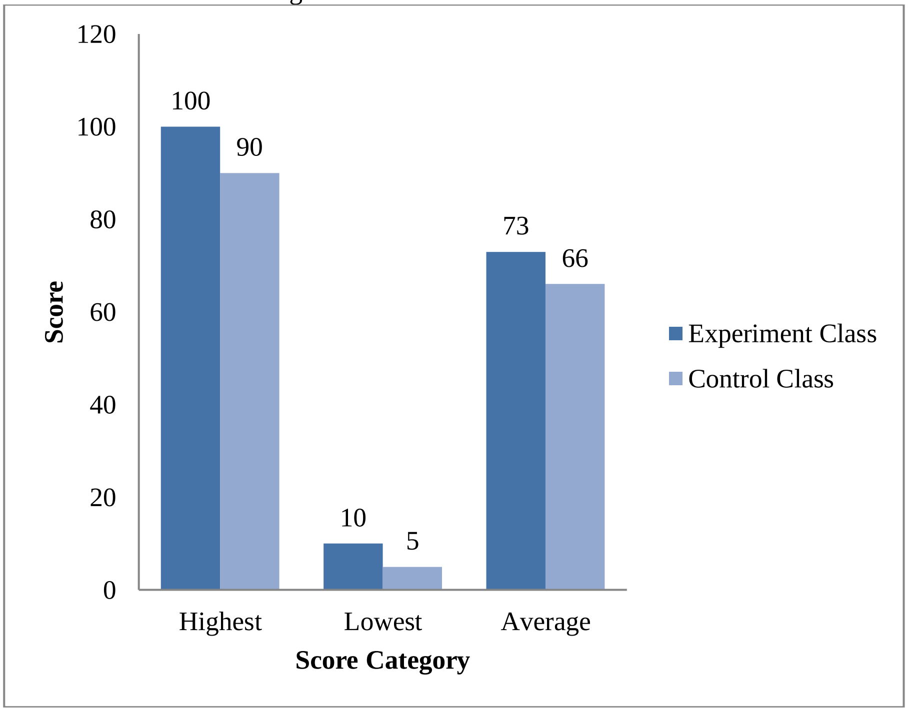

Fig. 1. Graph of Summative Assessment Results of Experimental and Control Classes

The results of the homogeneity test of the summative assessment values of the two classes can be seen in Table 7.

Table 7. Homogeneity Test Analysis Results of Summative Assessment Values

Kinds Result	Class	N	F_{count}	F_{table}	Category
Asesemen Sumatif	Experiment	36	0,76	1,72	Homogen
	Control	35			

Based on the results of the homogeneity test of the summative assessment scores of the two classes, the value is 0,76 and equal to 1,72 for a significance level of 5% . These results indicate that both classes are homogeneous.

3.1.3 Test Data Analysis Results

Before the hypothesis test is carried out, the homogeneity test and normality test of the data obtained from the test results are first carried out.

a. Homogeneity Test Results

This homogeneity test aims to determine whether the two data variances are homogeneous or inhomogeneous. If the data variance is homogeneous and normal, it can be followed up to test the hypothesis in accordance with the predetermined hypothesis test. The test results of the experimental class and control class can be seen in Fig. 2.

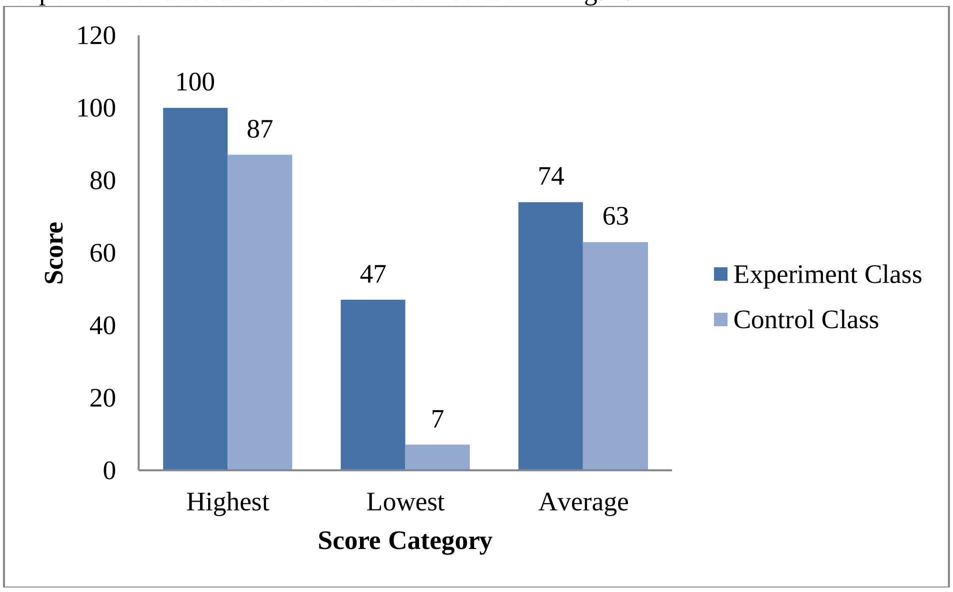

Fig. 2. Graph of Concept Understanding Test Results of Experimental and Control Classes

From the test results, an analysis was carried out to test the homogeneity of the data. The results of the test data homogeneity test can be seen in Table 8.

Table 8. Test Data Homogeneity Test Analysis Results

Stages	Class	N	F_{count}	F_{table}	Category
Posttest	Experiment	32	1,703	1,822	Homogen
	Control				

The results of the homogeneity test of the data from the concept understanding test results of the two classes show that the value is equal to 1,703 and the value is equal to 1,822 for the 5% significance level, so it can be seen that the value (1,703 lower then 1,822). It can be concluded that the data from the concept understanding test results of the two classes are homogeneous.

b. Normality Test Results

The normality test aims to determine whether the data is normally or abnormally distributed. The results of the normality test analysis of posttest data on understanding the concept of physics on static fluid material can be seen in Table 9.

Table 9. Normality Test Analysis Results Test Values

Stages	Class	N	x^2_{count}	x^2_{table}	Category
Posttest	Experiment	32	11,0313	11,0705	Normally
	Control	32	9,2103	11,0705	Distributed

From the test results of the normality of test scores, the experimental class value is 11,0313 and the control class value is 9,2103 with the experimental class value equal to the control class value of 11,0705 for a significance level of 5% (0,05). These results show that the value both in the experimental class and in the control class so it can be concluded that the test scores of the experimental and control classes are normally distributed.

c. Hypothesis Test Results

The hypothesis test used in the study was determined after conducting a homogeneity test and a normality test on the data. The results of the data analysis showed that the data obtained from the concept comprehension test in the experimental class and the control class were homogeneous and normally distributed. Based on the guidelines for selecting a hypothesis test, the test used is the pooled t-test, because the data produced is homogeneous and normally distributed. The degrees of freedom (df = n1 + n2) are used. The results of the pooled t-test from the concept comprehension test data are obtained as shown in Table 10 below.

Table 10. Results of The Pooled T-Test

Class	Number of Students (N)	Average	Variance (S^2)	t_{count}	t_{table}
Experiment	32	73,7188	230,0452	2,4866	1,9989
Control	32	63,1563	416,3656		

Table 10 shows that is (1.9989) at a significance level of 5%. According to the hypothesis testing criteria, if then H_0 is rejected and H_1 is accepted, which means that there is an effect of the problem-based learning model on high school student's understanding of physics concepts.

3.2 Discussion

The research aims are: to find alternative ways for high school students to understand physics concepts; and to find out wether there is an effect of problem-based learning models on students' understanding of physics concepts at senior high school. This study was conducted at SMA Negeri 2 Mataram from April to May 2025 using a pre-experimental design with an intact-group comparison design, which involved two sample groups: the first group received treatment (the experimental class) and the second group (the control class) did not receive the same treatment. The sample consisted of two classes: class XI science 5 as the experimental class and class XI science 8 as the control class. The selection of the sample was decided by the researcher based on recommendations from the physics teacher at SMA Negeri 2 Mataram and based on the summative assessment scores of the 11th grade science class in the even semester of the 2024/2025 academic year, which showed that the two classes tended to be homogeneous even though the average scores of the two classes were not same. The summative assessment scores can be seen in Figure 1.

Both sample groups were given treatment. In the experimental class, the treatment consisted of implementing problem-based learning on static fluid material with an estimated 3 meetings, each consisting of 2 lessons (6 lessons x 45 minutes), totaling 270 minutes. Meanwhile, the control class did not receive the same treatment, meaning that the treatment given in the control class was conventional learning, namely direct learning, with an estimated learning time of 270 minutes, divided into three meetings. However, due to time constraints imposed by the teacher at the school and the fact that there were several other programs that students had to participate in at the school, learning in each class could only be conducted in 2 sessions, totaling 180 minutes.

Nevertheless, students in each class still received all the material that should have been studied in the static fluid discussion, and the learning took place according to the syntax of each learning model, namely the problem-based learning model syntax in the experimental class and the direct learning model syntax in the control class. The problem-based learning model syntax consists of five stages, namely: (1) Organizing students around the problem; (2) Organizing students to learn; (3) Guiding individual and group investigations; (4) Developing and presenting the results of the work; (5) Analyzing and evaluating the problem-solving process. Meanwhile, the direct learning model syntax includes: (1) Communicating objectives and preparing students; (2) Demonstrating knowledge and skills; (2) Guiding training; (4) Checking understanding and providing feedback; (5) Providing opportunities for independent practice.

The technique used by the researcher to ensure that all material could be obtained by the students in less than the estimated time was to divide the types of problems to be solved by each group of students in the experimental class so that when each group presented their results, students from other groups could learn from them. This was done due to time constraints; otherwise, each group would have had to conduct investigations for all the problems set by the teacher, resulting in a more optimal experience and understanding of the concepts from the material studied. Meanwhile, in the control class, the researcher reduced some of the questions provided in the LKPD. The questions worked on by the students were questions that were directly related to the material studied and useful for the final test (posttest) of concept understanding provided by the researcher.

The concept comprehension test was administered to measure student's understanding of physics concepts, particularly in the material on static fluids, which included six concept comprehension indicators, namely C1 to C6 (Knowledge, Comprehension, Application, Analysis, Evaluation, and Creating). There are 15 questions, with 3 questions at the C1 level, 1 question at the C2 level, 5 questions at the C3 level, 3 questions at the C4 level, 1 question at the C5 level, and 2 questions at the C6 level. Before using these test questions, an instrument test was conducted to determine the suitability of the instrument to be used in the research activity. The following will discuss the instrument test that has been conducted.

3.2.1 Instrument Test Results

The research instrument tested in this case consists of a concept comprehension test with 20 multiple-choice questions. The instrument test was conducted at SMA Negeri 2 Mataram in the 11th grade science class 1 because the students in that class had previously studied static fluid material. The test questions prepared by the researcher were completed by 31 students in the 11th grade science class, and the results were analyzed by the researcher to determine the validity, reliability, discriminative power, difficulty level, and distractor test, enabling the researcher to conclude whether the test questions were suitable for use in the research.

The results of the concept understanding test using 20 multiple-choice questions showed that 7 questions were valid and 13 were invalid. All questions were unreliable. The difficulty level was categorized as easy for 12 questions and difficult for only 1 question. The discriminative power of the questions was categorized as good for 4 questions, sufficient for 4 questions, and poor for the remaining 12 questions. Based on this, the researcher decided to use 15 questions out of the 20 questions, which were then analyzed, resulting in 7 valid questions out of the total 15 questions. All of these questions were reliable. There was 1 question categorized as difficult, 2 questions categorized as moderate, and 12 other questions categorized as easy. There were 7 questions with poor discriminative power, 3 questions with adequate discriminative power, 4 questions with good discriminative power, and 1 question with very good discriminative power. The distractor test results showed that there were 3 questions with sufficient distractor effectiveness, 5 questions with poor distractor effectiveness, and 7 questions with very poor distractor effectiveness, meaning that they could not distinguish between students with higher or lower conceptual understanding, as the errors in the available options were very obvious. Therefore, since the researcher continued to use 15 items, the invalid items must be replaced or revised, followed by a retest. However, due to time constraints, the 15 items were revised, so it can be assumed that these items are valid and can be used for the research.

3.2.2 Problem-Based Learning Model Affects High School Students' Understanding of Physics Concepts

Based on the summative assessment results of grade XI science 5 students (experimental class) and grade XI science 8 students (control class), it can be seen that the average scores are still below the Learning Objective Achievement Criteria (LOAC) at SMAN 2 Mataram itself. The LOAC score at SMAN 2 Mataram is 81, while the average summative assessment score for the experimental class is 73 and 66 for the control class. From these assessment scores, a homogeneity test was conducted on both classes using the F-test, resulting in the conclusion that the classes are homogeneous, as shown in Table 7. This means that both classes can be used as research samples.

The researcher used an intact-group comparison research design, which is a research design that provides treatment to the experimental class in the form of learning using a problem-based learning model, while the control class is taught using a conventional learning model, namely direct instruction. After providing treatment to each class, the researcher administered a concept comprehension test to both classes to obtain data for analysis to determine whether there was an effect on the concept comprehension of students using the problem-based learning model compared to those using the conventional learning model.

The data from the concept comprehension test scores were first tested for homogeneity and normality to determine the appropriate type of hypothesis test to be used. After testing for homogeneity and normality, it was found that the post-test concept comprehension data in both classes were homogeneous and normally distributed, so the researcher used a parametric statistical test, specifically a paired t-test, for two unpaired sample groups. This means that the data tested were obtained from the post-test results of the experimental class and the control class, not from the pre-test and post-test results of the experimental class or the control class [9].

From the hypothesis test results, it was found that the value with the determination of the value for the two-tailed test, i.e., whether the problem-based learning model has an effect or not on students' understanding of physics concepts. The value while the value at a significance level of 5% or with its degrees of freedom using the formula n1 + n2 - 2 = 62, it can be concluded that there is an effect of the problem-based learning model on the understanding of physics concepts among high school students. This is in line with the research results of Aini et al. [10] that there is an effect of the problem-based concept acquisition learning model on students' understanding of physics concepts. This effect is manifested in the higher level of physics concept understanding among students in the experimental class compared to those in the control class. However, the type of material and sufficient time estimation for implementing the learning model must still be considered. As Sanjaya in Kurniawan et al. [11] stated, one of the limitations of this model is the need for sufficient preparation time.

Problem-based learning models influence students' conceptual understanding. This is consistent with the findings of Njaung et al. [12], who revealed that there is a significant difference in conceptual understanding between the experimental class using the Problem-Based Learning (PBL) model and the control class using conventional learning. Similarly, Ina et al. [13] also state that students' conceptual understanding is influenced by the learning model used, where students taught using problem-based learning achieve higher results compared to those using direct instruction or conventional learning.

Learning that begins by presenting problems in everyday life can increase their curiosity and make students more interested in learning, so that they are more active in their learning. This is supported by research conducted by Tania et al. [14], which states that students who engage in learning through the Problem-Based Learning model find it easier to understand the concepts being studied because, in this model, students are more interested in exploring physics problems commonly encountered in daily life. This interest motivates students to take their efforts to understand and solve problems more seriously and diligently. Thus, students do not merely memorize formulas but understand the concepts behind the problems studied in the material.

In implementing learning using the problem-based learning model, students are more enthusiastic and interested when, in the learning process, the problems set by the teacher are investigated or solved through experimental activities. This occurs in the research process conducted by researchers in the experimental class compared to learning in the control class, which uses the direct learning model. This aligns with what Zahara et al. [15] stated, that when using the problem-based learning model, students are not only inclined to memorize formulas but are more focused on how to solve problems through a series of scientific methods, such as observation, experimentation, data analysis, communication, and drawing conclusions. In other words, the use of a problem-based learning model can enhance students' understanding of what they are learning, enabling them to apply it in real-life situations.

Based on the above explanations, it can be concluded that using a problem-based learning model can enhance students' conceptual understanding of the material being studied, making it suitable for teachers to use in their teaching practices.

3.2.3 Challenges in Conducting the Research and Strategies for Resolution

This research was not without challenges or limitations, both from the system (learning model, students, field conditions) and from the researchers themselves. Among the challenges the researcher encountered during the research implementation were limitations in conducting investigations or experiments by students, who did not use the laboratory and equipment available in the school laboratory. This was due to permission issues at the school, so the researcher opted to use simple tools easily found in daily life and also utilized media such as the PhET Simulation application in one type of experiment conducted by the students.

In addition, the researcher also encountered obstacles in the form of time constraints to complete each stage of the problem-based learning model syntax according to the estimated time, meaning that the time estimated by the researcher was not sufficient for the students to complete their investigative activities. In this case, the researcher observed that the insufficient time to complete the investigation process according to the estimated time was due to: (1) Some students in each group still did not understand the purpose of the activity to be carried out, so they continued to wait for instructions from the researcher to carry out each stage of the investigation or experiment, even though the instructions were already available in the worksheet; (2) There were some students in each group who also did not fully understand the entire investigation instructions contained in the student worksheets, so they tended to be passive compared to other group members. This caused the cooperation between each group member to be less synergistic, so that activities that should have been completed more quickly when they worked together ended up taking longer to complete because not everyone was proactive in the investigation activities; (3) The researcher provided each group with only one worksheet, making it difficult for students in a group to flexibly read the instructions provided on the worksheet.

To overcome these obstacles, the researcher provided further explanation regarding the purpose of the investigation to be conducted by the students. The researcher also monitored each group during the investigation to ensure that every group member was actively involved in the investigation so that all students could gain experience and discover the concepts they were actually learning in the static fluid material. In addition, the researcher also provided opportunities for each group to ask questions when students encountered confusion or other obstacles in the investigation process. The researcher also gave permission for students to use their mobile phones to take pictures of the worksheets distributed to each group so that they could access the instructions provided in the worksheets.

Other challenges identified by the researcher, in addition to those mentioned above, were incidental challenges, such as some students needing permission to leave due to competitions, extracurricular activities overlapping with class hours, and other school programs, resulting in some students not fully participating in the learning process as intended. This prevented them from receiving the same education as other students. For this challenge, the researcher advised students to continue learning independently outside of class hours.

4. Conclusion

4.1 Conclusion

Based on the results of the research conducted at SMA Negeri 2 Mataram, data analysis, and hypothesis testing at a 5% significance level, it can be concluded that the problem-based learning model has an effect on high school students' understanding of physics concepts. Therefore, teachers can use the problem-based learning model as an alternative learning model to improve students' understanding of the concepts taught.

4.2 Recommendations

Based on the research conducted and the conclusions drawn, the following recommendations are made.

1. For researchers and teachers who will use the problem-based learning model in teaching, experimental activities or problem investigations should be conducted in the laboratory, so that permission to use the laboratory and the equipment available within it can be arranged in advance.
2. At the beginning of the lesson, the learning objectives and the objectives of the investigation to be conducted by the students should be clearly communicated, along with their connection to the sequence of investigative activities they will carry out, to avoid confusion among the students.
3. Researchers or teachers must carefully review the steps provided on the students' worksheets to ensure they are clear and unambiguous, minimizing the likelihood of students misunderstanding the sequence of investigative activities to be conducted.
4. The student worksheets provided should be sufficient for all students in the class to facilitate their access to the instructions on the worksheets, so that they do not need to use a smartphone as an aid to access the student worksheets, as the use of smartphones may distract students with content such as social media or games that are not necessary for the learning activity.

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