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# The Effect of Problem-Based Learning on Students' Conceptual Understanding Reviewed from Students' Beliefs

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***ABSTRACT***
*This study aims to analyze the effect of the implementation of problem-based learning on the understanding of physics concepts in terms of students' beliefs. This study is a quasi-experimental study with a 2 x 2 factorial design. The research sample was 50 students from class XI IPA SMAN 10 Kota Jambi, and they were divided into an experimental class (n = 25) and a control class (n = 25). Data was collected using a four-tier diagnostic test, observation sheets, and a learning implementation checklist. The results of the analysis used a two-way ANOVA test. The study results showed that students in the experimental class had a higher percentage of conceptual understanding (66%) than students in the control class (50.8%). There was no influence of beliefs (positive and negative) on the knowledge of physics concepts. There was no interaction between the problem-based learning model and beliefs on students' understanding of physics concepts on static fluid material.*

## INTRODUCTION

Physics is one of the compulsory subjects at the senior high school level in Indonesia, especially in the Mathematics and Natural Sciences (MIPA) specialization. Physics learning outcomes at the senior high school level are divided into two elements: physics understanding and science process skills. *Conceptual understanding* is students' main obstacle in learning physics [1]. According to Loyens et al [1], a coherent conceptual understanding of physics concepts entails restructuring students' preconceptions, and often, these preconceptions conflict with scientific perspectives. Preconceptions that conflict with scientific perspectives are called misconceptions and are one of the main obstacles for students in reconstructing a good understanding of physics concepts. Loyens et al [1] asserted, supported by research data, that students at both high school and college levels harbor misconceptions regarding numerous physics topics, including geometric optics [2], temperature and heat [3], fluid dynamics [4], and Newton's laws [5], among others. A systematic literature review conducted by Resbiantoro & Setiani [6] shows that misconceptions occur in almost all physics topics, especially in the material on force and motion, as seen in Figure 1 below:

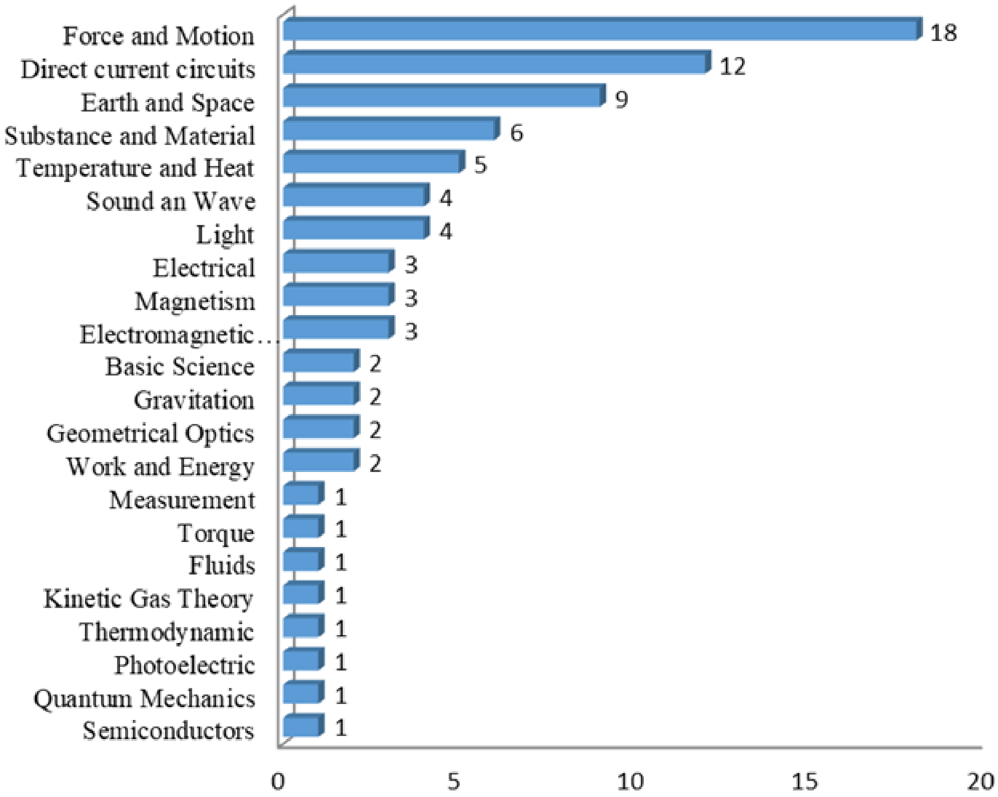


***Fig 1.*** *Physics Topics in Misconception Research*

Based on the constructivist perspective, students do not come to class as empty glasses waiting to be filled with new knowledge. New knowledge is formed through previous experiences and knowledge, meaning that students come to class with experiences they have gained from everyday life that form initial conceptions or preconceptions. These preconceptions can facilitate or hinder acquiring a complete understanding of physics concept [7]. If the preconceptions held by students are based on the actual concepts of physics, then these preconceptions can facilitate the understanding of physics concepts. However, if the preconceptions held by students are not by the scientific concepts of physics, then these preconceptions can hinder the understanding of physics concepts. A coherent understanding of physics concepts can be achieved if students master two types of knowledge, quantitative and qualitative, and a strong relationship between the two types of knowledge [8].

The preliminary study conducted by the researcher revealed that the physics learning outcomes of class XI MIPA students at SMAN 10 Jambi City were relatively low. Data on student learning outcomes showed that 58.8% of students had not achieved the Minimum Completion Criteria (KKM) set, which was 75. Meanwhile, the results of physics learning observations indicated that direct instruction still dominated learning. Although teachers have tried to use student-centered learning, the frequency of use is still limited. According to teachers, the main challenge in implementing student-centered learning is students' lack of basic knowledge. Furthermore, the results of interviews with physics teachers showed that teachers have never used diagnostic instruments to analyze students' understanding of physics concepts. The absence of this diagnostic instrument causes teachers to have difficulty in identifying concepts that are not yet well understood by students and misconceptions that may occur in the physics topics being studied. As a result, the learning strategies used by teachers so far have not fully helped students build a coherent conceptual understanding of physics concepts. This condition shows a very urgent need to implement a learning model that focuses on improving learning outcomes and allows students to understand physics concepts comprehensively through meaningful learning experiences.

A complete understanding of physics concepts can be obtained by restructuring students' misconceptions through instructional strategies designed to help students recognize conflicts between existing knowledge and scientific explanations [1]. According to Loyens et al [1], instructional interventions designed to encourage conceptual change will be effective if they allow students to compare and contrast their initial understanding with scientific concepts. Problem-based learning is one learning approach designed to facilitate conceptual change in students [9]. Problem-based learning (PBL) is a student-centered learning approach that facilitates students to activate prior knowledge, analyze critical arguments, and foster an in-depth understanding of scientific perspectives [10]. Shishigu et al [10] explained that the problems used in PBL are real-world problems that can be solved in various ways, thus encouraging higher cognitive engagement. In addition, PBL is a learning method that integrates all cognitive processes conducive to encouraging conceptual changes in students, such as discussions, critical argument analysis, and activation of prior knowledge [11]. PBL can be applied to various topics and has been successfully applied in various educational environments.

Research on the cognitive aspects of learners explains that the prior knowledge possessed by learners influences information-processing activities, from their perception of environmental cues to decision-making about how the information should be processed [12]. In the context of learning, learners' prior knowledge can influence how students understand new material by connecting it to existing knowledge and changing or expanding existing knowledge. However, Cartiff et al [12] stated that cognitive studies that only focus on mental aspects, such as memory and information processing, tend to be unable to explain why learners with adequate prior knowledge cannot activate that knowledge to complete specific tasks. Furthermore, Cartiff et al [12] stated that the inability of learners to activate their prior knowledge in understanding new material could be caused by factors originating from within the learner, such as low interest and motivation as well as learners' beliefs or beliefs regarding the characteristics of knowledge and how to obtain that knowledge. Hammer [13] categorized students' beliefs in a continuum into three different dimensions: beliefs about the structure of physics knowledge, beliefs about the content of physics knowledge, and beliefs about the process of learning physics. Beliefs about the structure of physics knowledge consist of two contrasting views: physics as a collection of separate facts, formulas, and definitions (pieces), or physics as a single concept that is so interrelated and coherent (coherence). Second, beliefs about the content of physics knowledge have two contrasting views: physics as knowledge that is memorized (formulas) or physics as a concept that requires deep understanding (concepts). Third, beliefs about learning physics are divided into two views: learning as a process of passively receiving information (by authority) or the belief that learning physics is a process of actively building knowledge (independently). According to Madsen et al [14], students' beliefs about the characteristics of knowledge and how to acquire knowledge influence their ability to learn and understand physics concepts. Madsen et al [14] stated that students' beliefs about knowledge and how to acquire knowledge determine how they choose and use learning strategies, and students' learning experiences can influence these beliefs in different learning designs.

Various studies have been conducted to explore the understanding of physics concepts using problem-based learning at multiple levels of education [15] [16] [17]. However, far too little attention has been paid to explicitly investigating the effect of problem-based learning models on understanding physics concepts about static fluid concept in terms of students' beliefs. This study aims to fill this gap by analyzing how students' beliefs moderate the effectiveness of problem-based learning in understanding physics concepts. The main objective of this study is to investigate the effect of using problem-based learning models on understanding physics concepts in terms of students' beliefs. This study will provide important implications for physics education by exploring how students' beliefs moderate the effectiveness of problem-based learning in improving students' understanding of physics concepts on static fluid material. This study contributes to developing literature on students' misconceptions by analyzing the relationship between problem-based learning, students' beliefs, and students' conceptual understanding.

## METHOD

This study uses a quasi-experimental design to analyze the effect of problem-based learning implementation on the understanding of physics concepts reviewed from students' beliefs using a 2x2 factorial design. The research variables consist of independent variables in learning models, attribute variables (beliefs), and dependent variables, namely students' understanding of concepts. The research sample is grade XI students of SMAN 10 Jambi City. Students were randomly divided into two groups: the experimental class and the control class. The experimental class received treatment by applying problem-based learning, while the control class followed the conventional learning model. The experimental class consisted of 25 students, and the control class consisted of 25 students. Before being given treatment, each student was given a diagnostic test to measure their understanding of the concept of physics material, namely buoyancy, at the beginning and end of the learning process.

The researcher used a four-tier diagnostic instrument to measure students' understanding of physics concepts on static fluid materials. The four-tier instrument consists of four levels: the first level is a question like a regular multiple-choice, the second level is the student's confidence in choosing the answer in the first tier, the third level is the reason for selecting the answer in the first level and the fourth level is the level of confidence in choosing the answer in the third level. The four-tier instrument used in this study results from developing and modifying the four-tier instrument developed by Herliana et al [7], which focuses on measuring students' misconceptions about buoyancy materials. Researchers added two new items that included other aspects of static fluid matter. These two items measure students' conceptual understanding of hydrostatic pressure. The researcher observed the learning process, including learning tools, processes, and student behavior. In this study, students' beliefs about physics and physics learning were measured using the CLASS (The Colorado Learning Attitudes about Science Survey) questionnaire instrument developed by Adams et al [18] and modified by Maison & Syamsurizal [19]. The CLASS questionnaire consists of 25 items and is divided into three dimensions: personal interest, conceptual understanding, and problem solving.

## RESULTS AND DISCUSSIONS

The students' conceptual understanding of physics concepts was measured on static fluid materials. Static fluid has many applications in daily life and includes three main concepts: hydrostatic pressure, Pascal's Law, and Archimedes' Principle. Although static fluids are widely used in daily life, various research shows that students still experience difficulties in solving problems related to this material Table 1. The following is a categorization of students' understanding of physics concepts in the control class and the experimental class:

**Table 1.** Categorization of Students' Understanding of Physics Concepts in Control Classes

| Categorization | Pre-Test | Post-Test |
|---|---|---|
| Scientific Concep Understanding (SCK) | 16.8% | 50.8% |
| Misconception (MSC) | 33.6% | 36.0% |
| Lack of knowledge (TPK) | 17.2% | 5.2% |
| False Positive (FP) | 21.2% | 6.0% |
| False Negative (FN) | 11.2% | 2.0% |

Based on Table 1. It can be seen that there is an increase in the percentage of students who have an understanding of concepts in the pre-test test and post-test test in the control class. In the pre-test test, only 16.8% of students had an understanding of the concept and increased to 50.8% in the post-test test. Meanwhile, there was a decrease in the percentage of students who did not understand the concept, namely 17.2% in the pre-test to 5.2% in the post-test, as well as in the percentage of students who had false postive and false negatives experienced a significant percentage decrease. However, the percentage of students who experienced misconceptions remained resistant and tended to increase from 33.6% in the pre-test to 36% in the post-test. The following Table 2 is the percentage of categorization of students' understanding of concepts in the experimental class in the pre-test and post-test tests.

**Table 2.** Categorization of Students' Conceptual Understanding of Physics Concept in The Experimental Class

| No | Categorization | Pre-Test | Post-Test |
|---|---|---|---|
| 1 | Scientific concept understanding (SCK) | 21.20% | 66.00% |
| 2 | Misconception (MSC) | 35.60% | 15.20% |
| 3 | Lack of knowledge (TPK) | 11.60% | 1.20% |
| 4 | False Positive (FP) | 15.20% | 6.80% |
| 5 | False Negative (FN) | 17.20% | 10.80% |

Based on Table 2, it can be seen that there is a very significant increase in the percentage of students' concept understanding from 21.20% in the pre-test to 66% in the post-test. Similarly, there was a substantial decrease in the rate of students who experienced misconceptions from 35.60% in the pre-test to 15.20% in the post-test. The category of not understanding concepts experienced a significant decrease from 11.60% to 1.20% in the post-test. The above data shows the effectiveness of using the problem-based learning model in improving students' understanding of concepts while reducing students' misconceptions about static fluid.

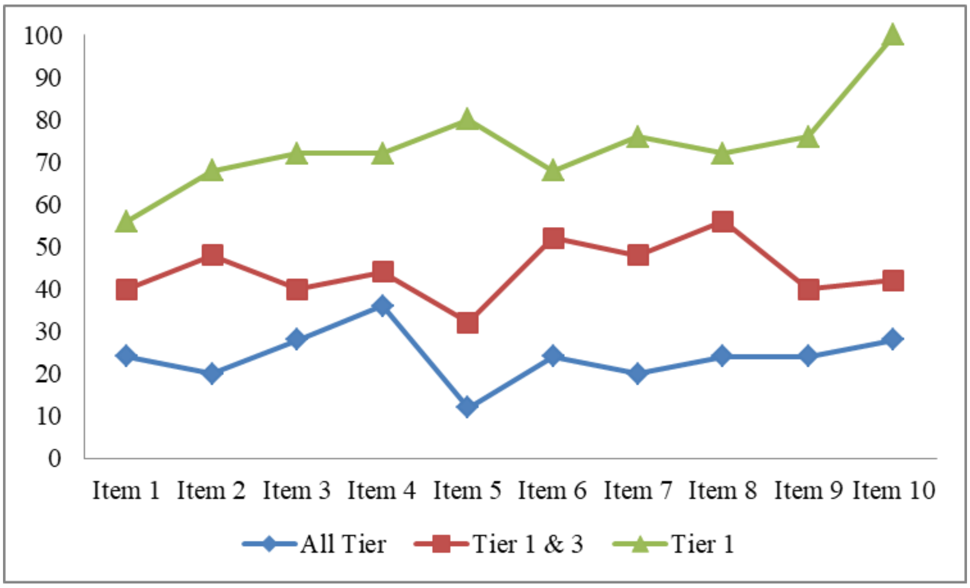


***Fig 2.*** *Percentage of Correct Answers at Tier 1, Tier 1 and 3, and All Tiers on the Post-Test of the Experimental Class*

Based on Figure 2, it can be seen that there is a decrease in the percentage of correct answer scores in each post-test question item in the experimental class. The percentage of correct answers in the first tier is always higher compared to the percentage of correct answers in tiers 1 and 3 and all tiers. This result shows that if the instrument only consists of one tier, such as ordinary multiple-choice instruments, the data produced is overestimated and does not fully represent students' understanding of the concept. The significant difference in the percentage of students who answered correctly in tier 1 with tier 1 and tier 3 and all tiers showed that students who were able to choose the correct answer in tier 1 still had difficulties when giving reasons to tier 3 and their level of confidence in answering tier 1 and tier 3. This result means that students can answer correctly in tier 1 because of the luck factor, not because they understand the concept. Meanwhile, descriptive statistics from students' beliefs data can be seen in Table 3.

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**Table 3.** Descriptive Statistics of the Dimension of Students' Beliefs

| Scale | Experiment | | Control | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Personal Interest | 3.95 | 0.95 | 3.65 | 0.82 |
| Conceptual Understanding | 3.05 | 1.16 | 3.25 | 0.81 |
| Problem Solving | 3.78 | 1.03 | 3.44 | 0.68 |

The results of the descriptive statistical analysis of the belief dimension of students in the experimental and control classes in Table 3 show that personal interest is the belief dimension with the highest average value in both the experimental and control classes, followed by the dimension of problem-solving and concept understanding. The standard deviation of the experimental class was higher in all dimensions compared to the control class, indicating a more significant variation in students' beliefs in the experimental class. The researcher categorized the beliefs of students in the experimental class and the control class into positive beliefs and negative beliefs, as seen in Table 4 below:

**Table 4.** Categorization of Students' Beliefs in Experimental Classes and Control Classes

| Categorization | Experiment | | Control | |
|---|---|---|---|---|
| | N | % | N | % |
| Positive | 17 | 68% | 10 | 40% |
| Negative | 8 | 32% | 15 | 60% |

A comparison of the percentage of students who understand concepts, misconceptions, do not understand concepts, false positives, and false negatives in the post-test in the control class and the experimental class on static fluid materials can be seen in Figure 3 below:

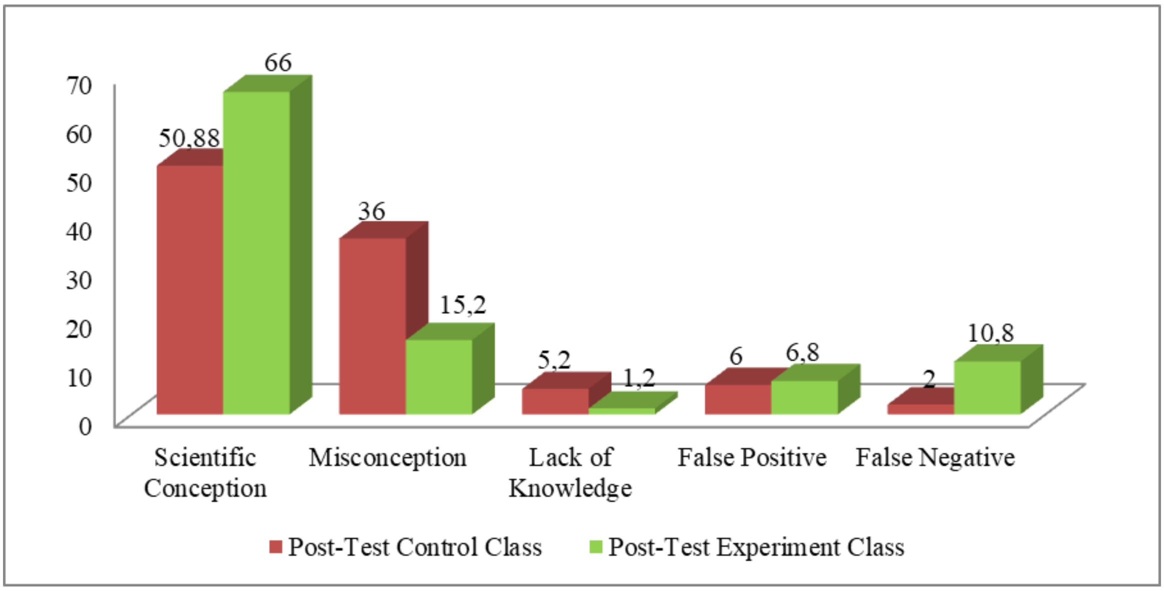


***Fig 3.*** *Categorization of Concept Understanding in Post-Test Tests of Students in Experimental Classes and Control Classes*

It can be seen in Figure 3 that students in the experimental class have a higher percentage of concept understanding (66%) compared to students in the control class (50.8%). Meanwhile, the rate of students who did not understand the concept in the experimental class (1.2%) was much lower than that of students who did not understand the concept in the control class (5.2%). On the other hand, the rate of misconceptions among students in the control class was higher (36%) than in the experimental class (15.2%). This data analysis is strengthened by the results of the Two Way Anova test, which proves that there is a significant influence of the use of the problem-based learning model on students' understanding of physics concepts on static fluid materials with an F value of 25,427, while the significance value is p = 0.000 < 0.05. This result signifies that problem-based learning models affect the students' conceptual understanding of static fluid material. This study's findings align with research conducted by Şenyiğit [20] stated that problem-based learning models invite activity and enhance students' conceptual understanding of physics. Through PBL, students are encouraged to understand and define the concepts needed to solve problems, and this process facilitates students entering the conceptual change process required for conceptual understanding. Çoban & Erol [21] stated that PBL is active and integrative learning that allows students to develop high-level thinking, problem-solving, and independent learning skills. Further, Çoban & Erol [21] mentioned that PBL is active, integrated, and constructive learning. Additionally, Çoban & Erol [21] noted that PBL is an active and integrative learning whereby students can develop high-order thinking, problem-solving, and independent learning. The results of the two-way ANOVA analysis showed that the intrinsic factor, namely the students' beliefs, did not have a significant effect on the students' understanding of the concept of physics on static fluid materials with a calculated F value of 0.996, while the significance value of p = 0.323 > 0.05. Based on the value of sig. Therefore, the alternative hypothesis is rejected, meaning that there is no influence (positive and negative) on students' understanding of physics concepts on static fluid materials. The results of the Two-Way ANOVA test for hypothesis testing whether there is a significant influence of the interaction between the problem-based learning model and participants' beliefs on students' understanding of physics concepts on static fluid materials obtained an F value of 0.754, while the significance value of p = 0.390 > 0.05. Based on the value of sig. Therefore, the alternative hypothesis is rejected, meaning that there is no interaction between the problem-based learning model and beliefs on students' understanding of physics concepts on static fluid materials. These results show the complexity of the relationship between students' intrinsic factors, namely beliefs and concept understanding. Beatson et al [22] stated that the relationship between beliefs and various learning outcomes, including understanding concepts, is not always linear and direct. Furthermore, Beatson et al [22] stated that the influence of beliefs on student learning outcomes can be mediated by other factors such as learning strategies and motivation. On the other hand, the results of research by Gaspard [23] show that the use of a student-centered learning approach can overcome obstacles that may arise due to students' negative beliefs.

## CONCLUSION AND SUGGESTION

Based on the researcher's analysis, it can be concluded that there is a difference in the use of the problem-based learning model on students' understanding of physics concepts in static fluid materials based on the results of the Two-Way ANOVA test with a significance value of p = 0.000 < 0.05. Students in the experimental class with the problem-based learning model had a higher percentage of concept understanding (66%) compared to students in the control class (50.8%). Beliefs (positive and negative) have no effect on students' understanding of physics concepts on static fluid matter based on the results of the Two-Way ANOVA test with a significance value of p = 0.323 > 0.05. There was no effect of interaction between the problem-based learning model and beliefs on students' understanding of physics concepts on static fluid materials based on the results of the Two-Way ANOVA test with a significance value of p = 0.390 > 0.05.

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