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## The Effect of Problem-Based Learning and Students' Understanding of Physics Concepts On The Topic of The Doppler Effect

Jamaludin <sup>1</sup>, Izaak Hendrik Wenno <sup>2</sup>, John Rafafy Batlolona <sup>3\*</sup>

Pattimura University, Ambon, Indonesia <sup>1,2,3</sup>

\*Corresponding E-mail: [johanbatlolona@gmail.com](mailto:johanbatlolona@gmail.com)

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Problem Based Learning;  
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### **ABSTRACT**

*Understanding the concept is one of the essential needs teachers pursue in improving student competence in the current era of openness. One of the learning models that can sharpen and encourage students' understanding of physics concepts is problem-based learning (PBL). Heretofore, research related to understanding concepts with PBL in understanding the Doppler effect material in depth is still minimal. Therefore, through this research, an exploration was carried out to determine the extent to which students' understanding of the Doppler effect material was carried out. The purpose of this study was to analyze the effect of PBL on students' conceptual understanding. This type of research is experimental with a total of 58 students. Both the experimental and the control classes were in class 11 of the science major of Christian Senior High School Ambon. The research procedure was a conceptual understanding test, which was carried out during the research process. The data analysis used was an independent sample T-test. The results showed that the average value of PBL class students' learning outcomes related to students' conceptual understanding was higher than conventional classes. It shows that PBL improve students' conceptual understanding of the Doppler effect material.*

## INTRODUCTION

In recent years, there has been a global outcry over students' low achievement in science subjects [1] and, in particular, physics learning at the secondary and tertiary levels [2]. In addition, significant concerns have been expressed about the rapid decline in the number of students choosing to enter college physics majors. Uganda has excellent experience in this area. For example, physics has been ranked as the worst-performing subject in final exams at the high school level [3]. The low achievement of learning physics is influenced by students' motivation and interest in learning [4].

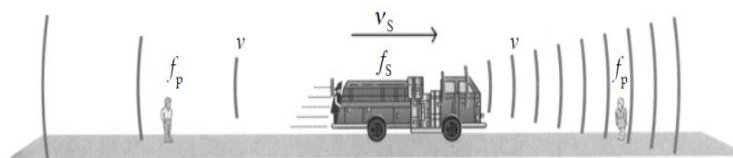
Learning physics is one thing that has its characteristics and requires skills in solving physics problems, as proven through theoretical and experimental mathematical calculations [5]. Physics learning emphasizes providing direct learning experiences by using and developing students' scientific skills [6]. One of the objectives of learning physics is for students to understand better and master the concepts of physics [7]. Recent studies have shown that learning outcomes improve when taught with virtual experiments when compared to actual experiments. This is the newest phenomenon discovered today [8].

Literature review shows that students, teacher candidates, and teachers still have many misconceptions in concepts (misconceptions) [9]. If this phenomenon is not quickly resolved, it will significantly affect current and future learning [10]. Students' understanding of physics for essay questions is still feeble when compared to multiple-choice questions. Students assume that essays create a high level of stress in solving problems compared to multiple-choice questions, giving small clues in sorting answers. In addition, the influence of socio-cultural perspectives and knowledge is built through language so that students have difficulty solving problems [11]. Therefore, teachers need to pay close attention to language and difficulty in making questions.

Understanding a concept is a thought process carried out by individuals to understand an object or event [12]. Understanding physics concepts is an essential part of learning physics. Good learning, one of which is the teacher can build conceptual understanding through simple activities through the phenomena around [13]. The teacher makes an analogy and uses simple language to convey information well to students [14]. Language and experience from teachers and students will be stimulations to relate phenomena in their daily lives with physics concepts explained by the teacher. [15].

Students consider the Doppler effect is one of the challenging physics concepts. It is shown in South Africa's physics learning, where physics results are still low [16]. Another research proved that 70% of students could correctly predict that the same periodic signal emitted by a different speed source (related to the receiver) will produce a different frequency signal. Only 50% of them can also predict that these frequencies will be the same if the sources have the same speed but are different from the receiver [17]. The study of the Doppler effect requires deep understanding. The lack of relationship or coherence among several concepts hinders students' conceptual understanding [18]. The Doppler effect is a phenomenon of intrinsic kinematic character [19]. The Doppler effect is a significant physics phenomenon with a wide variety of applications today. For example, some radars use this effect to determine the speed of moving objects. In astronomy, changes in the frequency of electromagnetic waves are used to measure the speed of stars and galaxies. In the medical field, the Doppler effect is used for image construction and measuring blood flow and other applications, namely in communication tools such as satellites and acoustics [20]. The Doppler effect was discovered in 1842 by Christian Doppler, who was an Austrian man [21]. The Doppler effect consists of a change in the frequency received by the receptor when the source moves relative to it, i.e. the frequency increases as the receptor approaches the source and decreases as the receptor moves away from the source [22]. This phenomenon occurs for the first time in the propagation of sound waves into the air [23]. The study proves that the study of the Doppler effect at the high school and college level is more theoretically studied and is still rare when studied with experimental studies in the laboratory [24]. Therefore, to overcome the difficulties faced by students, a strategy or learning model is needed that can encourage understanding in the concept of the Doppler effect. From this case, further research is explored on strategies or models that can support students' understanding of the Doppler effect. One of the recommended integrated strategies or models to increase students' understanding of the Doppler effect is problem-based learning (PBL). This study is quite different from the previous findings. The previous studies were more oriented in measuring students' concepts for the Doppler effect material with a concept map that refers to Pedagogical Content Knowledge (PCK). It makes a difference in Subject Matter Knowledge (SMK) Transformation which encourages physics teacher competence. [16] [25]. This research was conducted to improve the understanding of physics concepts on the Doppler effect with PBL. The Doppler effect is an event that changes the frequency of sound received by the listener because there is a change in the distance (relative motion)

between the sound source and the listener. The frequency received by the listener is greater than the frequency of the source if the distance between the source and the listener is getting closer and vice versa [26].



**Fig 1.** Sound source approaching observer [27]

Listener frequency fulfill the equation [28].

$$f_p = \frac{v+v_p}{v+v_s} f_s \quad (1)$$

The PBL model makes a significant contribution to students' learning [29] [30]. In PBL learning, students are empowered to analyze problems, make quick answers, analyze data, and conclude a specific answer based on the data obtained [31]. Therefore, the PBL model encourages students to think scientifically [32]. In addition, this model can help students discover and develop abilities cooperatively and make students lifelong learners [33]. PBL is one of the innovative learning models in the 21st century that can provide fun learning conditions for students [34]. In addition, PBL can improve critical thinking, interpersonal skills, problem-solving, generating new ideas, communication, collaboration, and teamwork. [35].

PBL emerged at the end of the 20th century. Harold Barrows developed this model at McMaster University Medical School to help students' dissatisfaction with their lectures in class [36]. PBL is a method that was first applied in the health sciences. It can be proved that PBL improves the interpersonal skills of nursing students in Iran [37]. The developer of this model recognizes that many medical graduates cannot correctly apply the content of the material learned in the classroom into clinical practice [38] [39]. This learning model is based on constructivist understanding [40]. The teacher acts as a facilitator and encourages students to find new meaning in learning [41]. Meanwhile, the learning environment is built to make it easier for teachers and students to interact and inquire in the learning process [42].

PBL can increase self-efficacy [43]. The PBL was conducted at the College of Dentistry, Qassim University, and Saudi Arabia in online learning at every meeting. The results show that students with outstanding and robust knowledge in small groups will build interactive and cohesive groups to produce good learning outcomes of 93.3% [44]. In addition, studies on secondary education show that PBL can promote mastery of social concepts and skills [45]. PBL encourages contextual-based learning in everyday life, which helps to improve students' thinking skills [46], increases creative thinking, and develops teacher and student skills in ethical and aesthetic aspects [47]. There are four essential elements of PBL for science, namely, a) the problem as a source of information that focuses on significant science with concepts, 2) there is an opportunity to test students' ideas through experiments, (c) students must manage their data, and 4) presentation of solution [48]. Based on existing studies, the purpose of this study was to analyze the effect of PBL on students' understanding of concepts.

## METHOD

This research is an experimental study that aimed to describe student learning outcomes by looking at

the initial and final tests after applying the experimental student worksheets using the PBL model. This research used a quantitative approach with a quasi-experimental type of research. Quasi-experiments were used to test the effect of PBL on students' understanding of physics concepts on the topic of the Doppler effect. The experimental design used a nonequivalent control group design. This study used a pretest and posttest group design for the experiment and control. The location of the research was at YPKPM Christian High School Ambon, Indonesia. The sample focused on 58 11th grade students from the science department for grades A and B. Class A as the experimental class and class B as the control class. The sampling technique was done by cluster random sampling technique.

The instrument in this study consisted of student worksheets and concept understanding test questions for the Doppler effect material as many as 10 questions in the form of diagnostic tests to measure the extent to which students' physics abilities were. Student worksheets were designed according to the PBL syntax to provide assessments to students during the learning process. The two techniques were used to obtain data in the study, namely tests and assessments. 1) A test in the form of a pretest was carried out before the learning process began. This test was conducted at the initial meeting to know the students' prior knowledge of the concept of the Doppler effect. Meanwhile, the posttest after the learning process was used to determine student achievement of what has been learned. 2) Assessment was carried out during the process to measure the expectations to be achieved, including the implementation of PBL model learning, student response questionnaire instruments when taught with PBL, interview instruments to re-check student understanding and documentation in the form of screenshots of student answers on worksheets or recordings when students answer questions given by the teacher.

The data analysis used in this study was done quantitatively. Quantitative analysis data was in the form of pretest and posttest results for understanding the concept. The requirement test was carried out and started from the normality test, homogeneity, and T-test with the assistance of the SPSS 16.00 for the windows program before testing the hypothesis

## RESULTS AND DISCUSSIONS

The following is a comparison of the scores from the pretest and posttest of students' concept understanding in the experimental class and control class as shown in Tables 1 and 2.

**Table 1.** Concept understanding test for pretest

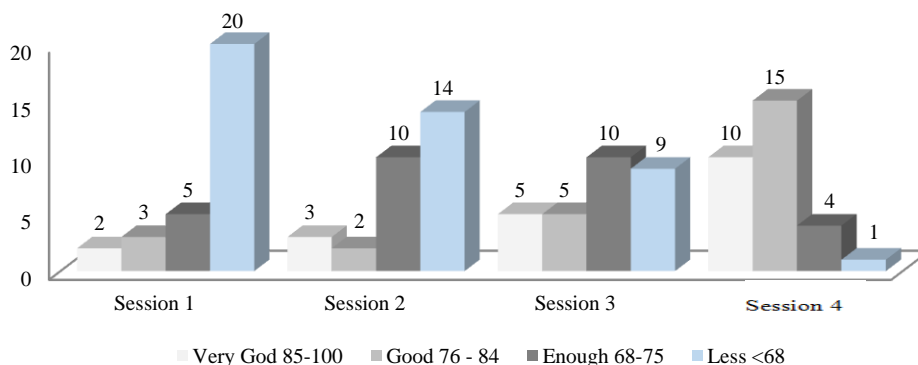
Classes	Number of Samples	Student Initial Ability Score		Average
		Highest	Lowest	
Control	29	81	23	47.17
Experiment	29	70	20	46.87

**Table 2.** Concept understanding test for posttest

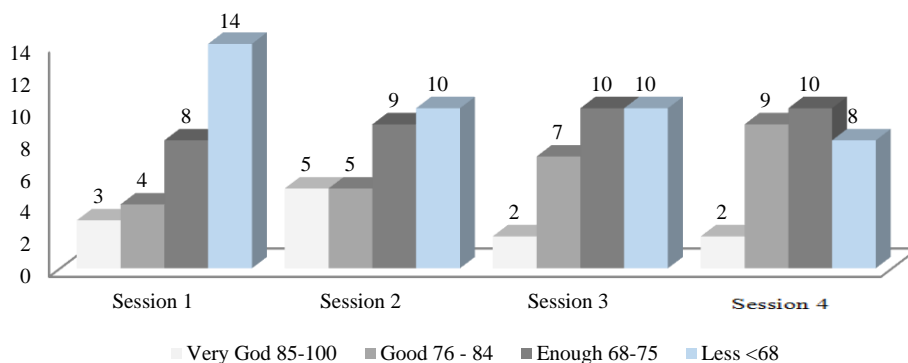
Experiment Worksheet	N	Mean	Minimum	Maximum
Conventional	29	53.7931	35.00	75.00
Experiment	29	60.6897	40.00	85.00
Total	58	57.2414	35.00	85.00

The data in Table 1 shows that the initial test of the control class is superior to the experimental class. In the final test, Table 2 shows that the experimental class is superior to the control class. The study results found that students taught with PBL had higher participant knowledge scores than the control class [49]. Learning was oriented towards understanding concepts with PBL support. It was beneficial and provided an excellent opportunity for students to understand the concept of the Doppler effect. PBL encourages students to be involved in real superior action through initial problems, class discussions, and presenting their work in front of the class [50]. In addition, it is in line with the results

of previous studies that PBL encourages guidance to see an idea analytically, not at the presumption stage but starting with the search for authentic evidence [51]. Students seem to be more enthusiastic in learning through small groups in completing assignments and making observations. They increase their activity in finding and solving given problems until they finally gain new knowledge. PBL is student-centered learning in practicing skills and the ability to solve problems. PBL is a small group teaching model which helps students become problem solvers [52]. In addition, PBL also increases self-confidence through activities to understand problems, plan solutions, solve problems, and increase students' self-confidence without being afraid to argue scientifically [53]. At each meeting, there is an increase in understanding of the concept. The results of achieving a conceptual understanding of experimental class students can be shown in Figures 2 and 3.



**Fig 2.** Qualifications for Achieving Conceptual Understanding of Experimental Class Students



**Fig 3.** Qualifications For The Achievement Of Conceptual Understanding Of Control Class Students

The data in Figures 1 and 2 show different results for the experimental class and the control class. The experimental class was superior and improved during each meeting compared to the control class. Students taught with PBL significantly improved students' conceptual understanding compared to students taught with conventional methods. Students taught with PBL using simulations engage in authentic problems that make them curious and think about solving physics problems. Instructions using PBL were unambiguous and provided many opportunities for students to collaborate during the experiment and resulted in more interaction between students and between students and teachers. Stimulus in the form of problem questions in everyday life can lead students to build their knowledge and help them think about answering and solving these problems [54]. In this case, students become more actively involved in learning when compared to ordinary learning.

PBL is based on the principle that student learning is aided by a combination of individual intellectual exploration and the ability to collaborate with others. For example, students must first be able to identify a problem related to a particular situation. Then, after the questions relevant to the overall learning objectives have been identified by the study group, students must provide possible solutions. In PBL practice, groups of six to nine students solve problems through group meetings. In addition, students also obtain, process, and organize information, both individually and as a group [55]. PBL has many benefits that can help students learn to be more active than passive in learning. In addition, PBL provides opportunities for students to solve real-life problems and have discussions. Moreover, students must be involved, understand, digest, absorb, and even construct knowledge itself. This study also shows that the PBI model is practical and useful for increasing students' understanding of teaching materials and students' memory in the long term. [56].

It should be remembered that with PBL, students are more focused on developing conceptual understanding in the learning process. PBL can make students identify problems, improve scientific understanding and develop creative thinking [57]. In the PBL phase, it can help direct students to think creatively to find solutions to problems. PBL can support creative thinking skills during the learning process and lead students to be more challenged to do learning [58].

Hypothesis testing in this study was carried out using T-test statistics at a significant level ( $\alpha = 0.05$ ). Before testing the hypothesis, normality and homogeneity were first tested. The normality test of concept understanding data used the criteria if (sig) > 0.05, the sample came from a normally distributed population, and if (sig) < 0.05, the sample did not come from a normally distributed population. Based on the SPSS output in the Kolmogorov-Smirnov column, the sig value in the class using the PBL learning model is  $0.045 < 0.05$ , and the conventional learning model is  $0.018 < 0.05$ . It means that the concept of understanding data in the control class and the experimental class are not normally distributed. The data being tested for homogeneity results from the student's concept mastery test in the posttest. Both the experimental class and the control class get a significant value of  $0.768 > 0.05$ . It means that the data is homogeneous.

The hypothesis testing in this study used SPSS 16 for Windows with the T-test. The hypothesis testing using the T-test requires normality and homogeneity of data. Based on the normality and homogeneity tests, the concept of understanding data meets the requirements for the T-test, as shown in Table 3.

**Table 3.** The results of hypothesis testing using the T-test ( $\alpha = 0,05$ )

Class	T <sub>count</sub>	T <sub>table</sub>	Sig. (2-tailed)	$\alpha$	Conclusion
Experiment and Control	3,125	1,677	0,002	0,05	H <sub>1</sub> accepted

From Table 3, it can be seen that the value of  $t_{count} = 3.125$  is greater than the value of  $t_{table} = 1.67$  and the value of Sig. (2-tailed) is smaller than the value = 0.05, which is 0.002. It shows that at the significance level = 5%, H<sub>1</sub> is accepted, and H<sub>0</sub> is rejected. These results indicate that H<sub>1</sub> is accepted and H<sub>0</sub> is rejected, which states that there are differences in concepts understanding of students taught using the PBL learning model and conventional learning models on the topic of the Doppler effect.

The probability value of the PBL learning model on concept understanding is less than 0.05, which indicates the PBL learning model affects understanding the concept of physics. The influencing factor is the understanding of the concepts of everyday life in learning physics. Learning activities start from contextual problems. By solving specific problems presented to them, students develop a deeper understanding of applicable concepts. They can apply these concepts in everyday life [59]. PBL emphasizes the importance of the active role of students in the learning process. It implies that students need to construct their knowledge rather than passively receive information. The PBL process can be divided into a pre-discussion, self-study phase, and a reporting phase. In pre-discussion, students begin the learning process by working in groups of 10 to 12 on a realistic problem, usually describing real-life situations and leading to group discussion. Students accept the problem at the beginning of the learning process before they learn about the topic of the problem [60]. They try to

provide possible explanations and solutions based on their experience and common sense, activating their prior knowledge. The advantage of this prior knowledge activation is that new information can be linked to existing knowledge, referred to as the elaboration process. Elaboration has proven to be beneficial in terms of knowledge retention. Prior knowledge is limited, some aspects of the problem being discussed remain unclear, and students collaboratively formulate questions about aspects of the problem that require further investigation and explanation. These learning problems guide students during their self-study period. Students individually select and study different literature sources to answer learning problems. After a few days of self-study time, students gather for the reporting phase. In this phase, the literature studied is discussed, and learning problems are answered in groups. The tutor, present during the pre-discussion and reporting stages facilitate the learning process by encouraging deeper thinking about the material being studied and asking students to apply the material discussed to other realistic cases [61]. Problem-solving and soft skills in PBL can improve students' employability after they graduate [62]. PBL also works to improve the programming competence of undergraduate students in computer science majors. Students gain experience with brainstorming, group work, speaking, writing, independent study, and problem-solving [63].

It provides an opportunity for students to discover new knowledge into the prerequisite knowledge for active problem solving [64]. The application of the PBL model can help and guide students to look at a new idea analytically and start at the presumption stage but start with the search for authentic evidence. The thinking ability possessed by students begins to be honed and accustomed so that it can have a long-term effect in problem-solving and critical thinking activities. The results of previous studies showed that the results of the control class on indicators defining terms had a high percentage [65]. This is because students in the experimental class are more likely to find a solution and interpret every existing learning process when compared to the control class, which memorizes every term that the teacher reaches. PBL learning that is oriented towards understanding the concept influences self-confidence. During the learning process, students and lecturers conduct discussions without blaming each other but rather confirming each other's opinions based on accountable sources. Students' feelings of anxiety and fear are not visible. [66].

PBL is more effective than conventional-based teaching methods in increasing students' conceptual understanding of the topic of the Doppler effect. Ini allows the development of students' conceptual understanding. In addition, these results may be obtained due to the effect of PBL on student learning. Students' cognitive level plays a vital role in students' mental construction. When the learning environment is designed to improve students' conceptual understanding and problem-solving, students' problem-solving skills improve. The initial knowledge of students who are still focused on memorizing will be transformed mentally with more meaningful and permanent knowledge [67]. Students have found the correct learning pattern, and this learning environment is already available with a PBL approach. The most challenging process of PBL is to prepare a design that fits the needs of students. In addition, as a teacher in implementing PBL, it gives a sense of interest and comfort to each group. In addition, the PBL class arrangement does not have too many groups with a small number so that the groups can be noticed. In addition, learning is more effective with a few groups, and learning materials that are difficult for students to understand can be digested well [68].

The students believe that physics is one of the most challenging disciplines in the school. They believe that only specially gifted students understand the concept. However, the research findings show that students' understanding of physics can be improved by using PBL. PBL allows students to understand physics better. PBL is one of the more effective teaching models for physics compared to conventional teaching methods [62]. Therefore, PBL is one of the alternatives to improve students' understanding of physics concepts. In addition, PBL helps students understand physics material, solve problems, and be able to connect and construct different ideas [63]. In addition, PBL can stimulate students' critical thinking, help improve scientific reasoning and store knowledge or information for an extended period. [69].

## CONCLUSION AND SUGGESTION

The application of the PBL model has been shown to increase students' conceptual understanding of the Doppler effect material. In addition, physics understanding of the Doppler effect taught using PBL is better than conventional learning. Thus, PBL can be recommended in facilitating and improving students' understanding of the Doppler effect material. The results of this study serve as information and constructive solutions so that teachers can design learning in the classroom and choose the right learning model that is student-centered. In addition, teachers can innovate in designing learning oriented to students' understanding to think in finding, designing, and providing concrete solutions to everyday physics problems.

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