



# Application of Problem-Based Learning Assisted by Virtual Laboratory on Light Wave Material to Improve Student Learning Outcomes of Class XI IPA 1 SMAN 1 Gorontalo

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**Abstract.** This study aims to evaluate the improvement in student learning outcomes on light waves, student activity in learning, and the teacher's ability to carry out learning using problem-based learning assisted by a virtual laboratory in class XI IPA 1 at SMA Negeri 1 Gorontalo in the United The research was conducted in May of 2023. This type of research was conducted through Classroom Action Research (CAR) in two cycles consisting of four stages: planning, implementing, observing, and reflecting. The participants of this study were peer teachers. The data collection instrument consisted of questions from the Learning Achievement Test, student, and teacher activity observation sheets. The data were analyzed using descriptive statistics. The results demonstrated that (1) the percentage of individual completeness increased from cycle I to cycle II, namely 77% to 87%, (2) there is an improvement in teacher learning implementation activities in the very good category, (3) There is an improvement in student activity during the learning process with a good category. From this study, it can be concluded that the application of a problem-based learning model assisted by a virtual laboratory can improve the physics learning outcomes.

**Keywords:** problem-based learning, virtual laboratory, physics education

## 1 Introduction

Education is a fundamental undertaking in establishing a learning environment and process that enables students to actively cultivate their potential, including religious spiritual strength, self-discipline, personality, intelligence, noble character, and the necessary skills for themselves, society, the nation, and the country. In this 21st-century era, the quality of a nation's life is largely determined by education. The role of education is crucial in creating an intelligent, peaceful, and democratic society. According to Jean Piaget, education functions as a bridge between individuals who are developing social, intellectual, and moral values that are the responsibility of educators in encouraging the development of these individuals [1].

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One of the principles of the 2013 curriculum is to encourage students to be active in the learning process. In contrast to the conventional approach, namely the teacher conveying information directly to students, the 2013 curriculum emphasizes student observations of certain phenomena or events, thereby arousing students' curiosity about these phenomena. In this curriculum, the teacher primarily acts as a motivator and facilitator, but also provides explanations and improvements to students' work at the conclusion of the core activities.

Physics has a very significant role in advancing science and technology. As part of the natural sciences, physics is seen as a unit of knowledge (body of knowledge), way of thinking (way of knowledge), and research methods (way of investigating). As a unit of knowledge, physics includes facts, concepts, legal principles, and theories. Physics learning enables students to master knowledge, concepts, and principles, as well as develop skills in applying and developing knowledge about natural phenomena related to physics.

Based on observations made at SMA Negeri 1 Gorontalo on February 13th, 2023, it is known that conventional learning approaches are still often used. Students gain knowledge through note-taking activities in books, explanations from the teacher, and working on sample questions and exercises. Students are only involved in listening, taking notes, and completing assignments according to instructions. The impact of this approach is student learning outcomes that are not in line with expectations. Therefore, teachers must expand this knowledge by empowering students to discover new things for themselves through learning experiences.

Each school has KKM standards (Minimum Completeness Criteria) set for each subject. Students are considered to have achieved completeness if they meet the minimum standard of completeness criteria [2]. Achievement of student completeness is influenced by supporting factors in the learning process, and the lack of these supporting factors can be an obstacle for students in achieving completeness." The KKM score for physics in class XI IPA 1 SMA Negeri 1 Gorontalo was set at 75. However, when the evaluation was carried out, only 11 out of 31 students in class XI IPA achieved or exceeded the KKM score, which means that only about 35% of students managed to reach the standard. The rest did not reach the KKM score or scored below 75.

The process of acquiring knowledge can occur if the teacher can create learning conditions that are in accordance with the characteristics of science learning and pay attention to students' perspectives. Learning that focuses on student activity takes precedence in this regard. If the teacher succeeds in creating an atmosphere that motivates students to be active in learning, it will be possible to increase learning outcomes [3]. Learning outcomes are one of the factors that influence the learning process. Student learning success is measured based on the extent to which students master the subject matter, but the learning process can also be determined by the extent to which students can utilize their brain's ability to solve problems.

From this description, it is essential to implement a learning approach that enhances students' comprehension of physics concepts. The 2013 curriculum recommends Problem Based Learning (PBL) as one effective model, as it has been shown to stimulate higher-order thinking by presenting problems within real-world contexts. Problem-based learning encourages the activation of advanced thinking skills in problem-solving

scenarios, including the methods students use to learn. This model emphasizes addressing real-life issues through genuine investigations [4].

PBL as a learning model designed to help students gain important knowledge in solving problems, developing their learning models, and having the ability to participate in groups [5]. The phases of Problem-Based Learning (PBL) entail orienting students to the problems, organizing them, providing guidance for individual and group investigations, creating and presenting work, and analyzing and evaluating the process of problem-solving. The Project-Based Learning model has the potential to positively impact student learning outcomes and interests. This is due to several advantages of PBL, such as encouraging students to develop problem-solving skills in real-life situations and enabling them to construct knowledge through active learning activities [6].

The material of light waves is often considered difficult by students in physics lessons because learning only focuses on formulas without understanding related physical phenomena. To overcome these problems, one of the steps that can be taken is to apply different learning models, with the hope of improving student learning outcomes and enabling them to develop an understanding of solving problems. Some learning models based on constructivism, such as Problem-Based Learning (PBL), direct students to the process of solving problems.

Learning activities on the material of light waves, the sub-topic of the properties of light, will be better and more interesting if there are practical or experimental activities to make it easier for students to see the symptoms that arise from the properties of light. However, the equipment in the SMAN 1 Gorontalo laboratory is still limited, so it cannot be used to carry out these experiments.

Along with the changing times, activities in the classroom are increasingly being supported by the development of various learning media. Learning media refers to all forms used to convey messages or information in the teaching and learning process, with the aim of arousing students' interest and attention toward learning [7]. Learning media is an important component that assists educators in conveying learning objectives to students. In terms of gaining an understanding of the wave properties of light, researchers use virtual laboratory media known as PheT Simulation and Physics: Interactive Physics Simulations based on Macromedia Flash and Java software.

Virtual laboratories can be a tool for teachers or instructors in conducting practicum at school. By using interactive computer media, virtual-based practicums can be carried out. The virtual laboratory provides support for a practicum that is interactive, dynamic, and animative and is in a virtual environment so that it is not boring and encourages user interest in learning and understanding productive subject matter in secondary schools. Other research results in 2019, it was stated that virtual laboratories can improve students' cognitive competence (concept understanding) and psychomotor (motor skills) [8].

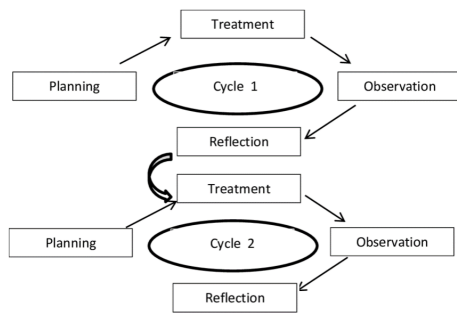
Given the problem, researchers are interested in investigating and gathering information about the "Application of Problem-Based Learning Assisted by Virtual Laboratories on Light Wave Material to Improve Student Learning Outcomes of Class XI IPA 1 SMAN 1 Gorontalo".

## 2 Method

The research conducted is a type of classroom action research. Classroom action research (CAR) is research that can be carried out by teachers to improve the learning process to achieve the desired goals. The implementation of PTK is very relevant to the role of a teacher as an educator, instructor, mentor, coach, and evaluator of student learning outcomes. In this context, PTK is seen as the most appropriate form of research to improve the quality of learning, because apart from being a researcher, the teacher also acts as an executor of the learning process, thus understanding the problems faced and the conditions to be achieved [3].

A key characteristic of action research is the active participation and collaboration between researchers and the members of the group being studied. Action research serves as a problem-solving strategy that employs concrete actions through innovative developments, tested iteratively to identify and resolve issues. Throughout this process, the involved parties can provide mutual support.

The research flow model was adapted from the class action research flow according to John Elliot. If there are errors or deficiencies in the implementation of learning, then the learning will be corrected and modified, then proceed to the next action plan, and so on. This cycle will continue until the actions taken are considered good or stopped because the data collected is sufficient and the class conditions are stable. In this study, the action taken was to apply a problem-based learning model in which practical activities were using a virtual laboratory PhET and Physics on the material of light waves, the sub-topic of the properties of light waves.



**Fig. 1.** CAR flow according to John Elliot

This study was conducted at SMA Negeri 1 Gorontalo during the period from 2 to 30 May 2023, during the even semester of the 2022/2023 academic year. The research subjects consisted of 31 students from class XI MIPA 1 at SMA Negeri 1 Gorontalo, from class XI MIPA 1. In this study, two types of instruments were used, learning tools and data collection instruments. Learning device instruments encompass Learning Implementation Plans, learning media, teaching materials, and Student Worksheets. The data collection instruments consisted of test results, observation sheets of student activities, and observation sheets of the teacher’s ability to carry out learning.

The data obtained from the observation of student activities and learning outcomes was analyzed descriptively. Descriptive analysis describes the outcomes of the data gathered without making any generalizations or drawing general conclusions. Data on student learning outcomes were analyzed using the class average score system from student learning outcomes tests in each cycle using the class average score system from the student learning outcomes tests. [9].

This research comprised four stages: planning, implementing, observing, and reflecting. During the planning stage, the researcher prepared research instruments, including learning tools and data collection tools. The actions in cycle I were implemented in accordance with the activities outlined in Learning Implementation Plan 1. For cycle II, actions were adjusted based on reflections from cycle I. Observers simultaneously observed student activities during the learning process during the observation stage, with the objective of gathering data for reflection. The final stage, reflection, was conducted after each action cycle to enhance and optimize the subsequent implementation.

The data analysis technique in this study used a percentage test with a quantitative method.

$$P = \frac{f}{N} \times 100\% \quad (1)$$

Where:

P : percentage sought

f : frequency of students who complete

N : total students A student's individual mastery of the material is deemed achieved when their score meets or exceeds the KKM threshold of 75. Meanwhile, classical completeness will be achieved if 85% of students succeed in passing the KKM score. Good teacher learning activities are carried out by the teacher if a minimum of 80% of lesson plan implementation is achieved and very good if it reaches 90% and above [10].

Student activity observation sheets were prepared using a Likert scale with 4 criteria. The rules for assigning a Likert scale score are 4 – often appears, score 3 – sometimes appears, score 2 – seldom appears, score 1 – does not appear. Furthermore, quantitative data is interpreted into qualitative data based on the provisions of the ideal mean score and ideal standard deviation [11].

**Table 1.** Categorization of Student Activities

Score Range	Category
$x \geq 3.25$	Very good
$3.25 > x \geq 2.50$	Good
$2.50 > x > 1.75$	Fair
$x < 1.75$	Not good

Student activity will be reflected in the conversion table. If a value x is obtained more than or equal to 2.50, it is categorized as good in participating in learning activities and very good category if the value x is more than or equal to 3.25.

### 3 Result and Discussion

In this study, the approach involved applying a problem-based learning model with support from a virtual laboratory for teaching physics. Each session followed the PBL framework, with regular assessments and reflections conducted at the end of each cycle.

The research collected data through observations of teachers classroom teaching abilities, monitoring of students learning activities, and formative test results across each cycle. The research analysis was conducted by describing the description of the conclusion of each student cycle, the description of student activities, and the description of the teacher carrying out learning activities using a problem-based learning model on the material of light waves, a subtopic of the properties of light.

#### Cycle 1 Research Results

The preparatory steps carried out in planning cycle 1 include: (1) preparing student observation forms, (2) determining the material to be taught during the research period to find out the basic competencies that will be conveyed to students in learning, namely the properties of light on the interference subtopic and diffraction of light waves, (3) making a Learning Implementation Plan that uses a problem-based learning model with the support of a virtual laboratory, and (4) preparing learning media to be used.

Implementation In cycle I the first meeting was held on Tuesday 9 May 2023 with the material of light waves, the sub-topic of the nature of light, and a discussion of interference and diffraction of light waves. The second meeting was held on Wednesday 10 May 2023. In the indicator cycle the students wanted to achieve were (1) Finding the right concept of interference and diffraction of light waves; (2) Applying the interference and diffraction equations of light waves to solve problems.

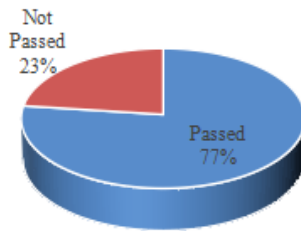
In the first cycle, the preliminary, core, and closing activities went well. The teacher carries out tasks such as attendance, apperception, and motivation, and conveys indicators and learning objectives. Meanwhile, students are active in orientation activities, organizing, mentoring experiences, developing works, and analyzing and evaluating the process of solving problems related to the wave nature of light, including interference and diffraction. In core activities, technology is used through the use of pictures, videos, and PhET Simulation virtual labs.

Implementation of learning achieves a value of 82% or good category. However, in this cycle, the average student activity only achieved a score of 2.67, or the sufficient category, because they tended to be shy in asking questions or opinions and focused more on preparing for their group work than paying attention to the results of other group work. The learning outcomes in the first cycle only reached 77% of students who passed, as seen in the student scores table.

**Table 2.** Student Learning Outcomes Cycle 1

No	Description	Frequency	Percentage(%)
1	Passed	24	77
2	Not Passed	7	23

From the data listed in the table above, it can be concluded that in the first cycle, the average student learning outcome was 80.1 with a percentage of 77%, which means that 24 out of 31 students succeeded in achieving learning mastery. However, classically, not all students achieve learning mastery, because only 77% achieve a score of  $\geq 75$ , while the minimum expected percentage of completeness is 85%. Therefore, there are 7 students, or 23% who have not achieved learning mastery. This information can be obtained more clearly through the following diagram, which is based on the table of values and the explanation of the first cycle values.



**Fig. 2.** Diagram of student learning outcomes cycle 1

Based on observations made by researchers and colleagues on the implementation of learning Physics using a problem-based learning model with the help of a virtual laboratory, it was found that teachers have good skills in managing learning with the model Problem Based Learning (PBL) at all stages, starting from the introduction to the core activities. In summary, the teacher's ability to manage learning using the PBL model in the first cycle can be categorized as good. During the first cycle, student activity received a score of 2.67, which is also considered to be good.

The reflection results which are supported by observational data conducted by researchers reveal the following things: (1) In analysing the nature of interference and diffraction of light, students still pay little attention to aspects related to the material; (2) Students still experience confusion in finding, creating, and presenting the results of the analysis found from solving problems related to interference and light diffraction; (3) The teacher has not optimally explained aspects related to light waves; (4) Most students still experience difficulties in using PhET as a learning medium; (5) There are still many students who are reluctant to ask questions, even though they do not fully understand the concepts to be learned and the explanations given by the teacher to find problems in the material being discussed.

To improve the quality of learning in cycle II, the following corrective steps are needed: (1) Before starting the group discussion, the teacher explains in detail the steps of learning using the PBL model and provides guidelines that must be considered in the discussion regarding the material characteristics of light waves that will be discussed.; (2) The teacher explains in detail the initial steps in finding problems to be analysed related to light waves, especially in terms of light polarization and its application in

everyday life; (3) The problems given must be more relevant to real life so that students are more motivated to study and solve these problems; (4) Teachers will more often give challenging questions, which encourage students to be better prepared in solving problems; (5) The teacher will provide learning materials that clearly explain how to use the virtual laboratory Physics; (6) The teacher will supervise and control students who are not active in working in their groups

## Cycle 2 Research Results

Upon analyzing observational data during the second cycle of applying the Problem-Based Learning (PBL) model, an improvement in student engagement was evident. The evaluation of the implementation of learning activities was conducted through observations conducted during each session, closely aligning with the planned activities.

The preparatory steps undertaken in planning cycle II are as follows: (1) Creating student observation sheets. (2) Determine the material that will be carried out during the research to understand the basic competencies that will be conveyed to students in learning, namely light waves, and the sub-topic of the properties of light (polarization and its application in everyday life). (3) Develop a learning implementation plan utilizing a problem-based learning model supported by a virtual laboratory Physics. (4) The preparation of learning media for use.

In cycle II, the first meeting was held on Wednesday, 17 May 2023, and the second meeting was held on Tuesday, 23 May 2023. The material discussed was the properties of light waves related to polarization and its application in everyday life. The indicators that students want to achieve in this cycle are: (1) Understanding the concept of the correct polarization of light waves; (2) Using the interference and diffraction equations of light waves to solve problems; (3) Applying the concept of light polarization in everyday life.

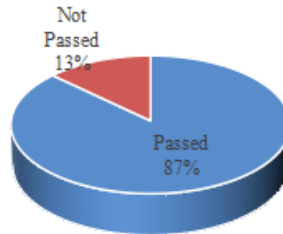
In the second cycle, the preliminary, core, and closing activities went very well. The teacher carries out tasks such as attendance, apperception, motivation, and conveys indicators and learning objectives. Meanwhile, students are active in orientation activities, organizing, mentoring experiences, developing works, and analyzing and evaluating the process of solving problems related to the wave nature of light, the sub-topic of polarization, and its application in everyday life. In core activities, technology is used through the use of images, videos, and virtual laboratories Physics Simulation.

Implementation of learning achieves a value of 91% or a very good category. In this second cycle, the average student activity has reached a score of 3.17, or a good category, because there is still a small number who are shy in asking questions or opinions and are more focused on preparing for their group work than paying attention to the results of other group work. The learning outcomes in the first cycle have reached 87% of students who have completed, as seen in the student scores table.

From the data listed in the table above, it can be concluded that in the first cycle, the average student learning achievement was 82.4 with a percentage of 87%, which means that 27 out of 31 students succeeded in achieving learning mastery. Classically, completeness has reached 87% and meets the minimum expected completeness of 85%. This information can be obtained more clearly through the following diagram, which is based on the table of values and the explanation of the first cycle values.

**Table 3.** Student Learning Outcomes Cycle 2

No	Description	Frequency	Percentage(%)
1	Passed	27	87
2	Not Passed	4	13

**Fig. 3.** Diagram of student learning outcomes cycle 2

Based on the observations of researchers and collaborators on the implementation of learning Physics using the PBL learning model with the help of a virtual laboratory, it can be seen that there is an increase in student learning outcomes as seen from the increase in the percentage of students who reach the completion criteria. The teacher made several improvements to improve student learning outcomes, namely: (1) Before starting a group discussion and looking for a solution to the problem, the teacher explains the steps that must be considered in the discussion and what needs to be analysed related to the material on the characteristics of mechanical waves that will be discussed in the lesson; (2) The teacher explains the first steps in finding problems and guides students on how to solve these problems; (3) The teacher provides clearer instructions on using the Physics virtual laboratory.

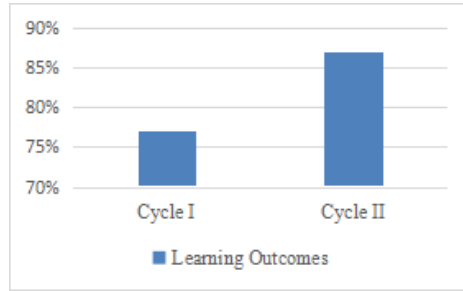
The teacher's learning management skills experienced a significant increase from the previous cycle to the second cycle. This can be seen from the increase in teacher skill scores. This success shows that the teacher has succeeded in presenting learning according to the expected criteria, including the ability to monitor student work, supervise group discussions, and arouse student enthusiasm for learning.

In the second cycle, the researcher succeeded in overcoming several shortcomings, including: (a) giving problems that were relevant to real life to facilitate students' understanding, (b) better supervision of students so that almost all students were active in their groups, and (c) providing more varied examples as reinforcement.

Based on the analysis of student learning outcomes data from cycle II, it is evident that there was a significant rise in student learning outcomes, exceeding the designated target, with a completeness level of 87%. Therefore, this research was stopped and not continued to cycle III.

The results of this study indicate that the use of problem-based learning methods assisted by virtual laboratories has a positive effect on improving student learning outcomes. This can be observed from the increase in students' understanding of the mate-

rial of light waves, especially in the sub-topic of the properties of light waves. The level of learning completeness increased from cycle I by 77% to 87% in cycle II. In cycle II, students’ learning completeness in Physics subjects has been achieved classically. This information can be seen in the following histogram.



**Fig. 4.** Graph of comparison of learning outcomes

For students classical learning scores, a score of 80.1 was obtained in the first cycle, and a score of 82.4 was obtained in the second cycle. In cycle II, students’ learning completeness reached classically 82.4% based on the percentage of action success. Based on the research findings and discussions, it is evident that utilizing a problem-based learning model aided by a virtual laboratory has enhanced the learning outcomes of class XI IPA 1 SMAN 1 Gorontalo in Physics, particularly in the subtopic of light wave properties, from cycle I to cycle II. This conclusion is consistent with previous studies indicating that implementing the Problem-Based Learning model can enhance students’ analytical skills [12]. This indicates that the teacher has started to encourage students to explore concepts through the implementation of PBL after the learning process. Findings from a 2012 study also support these results, showing heightened learning activities and improved student outcomes through the use of a problem-based learning model [13]. Similarly, a 2017 study applied PBL in web-based Basic Electronics courses for physics education students, revealing increased engagement from cycle I to cycle II [14]. Thus, employing PBL in education can boost student activity and learning outcomes through targeted instructional improvements.

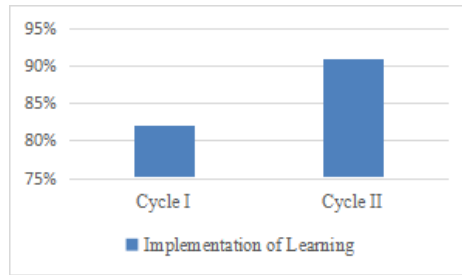
**Table 4.** Student Activities

No.	Categories	Combination of answers	
		Ordinary multiple choice test options (Tier-I)	Confidence of levels options (Tier-II)
1	Misconceptions (MC)	Incorrect	Yes, I am sure
2	Understand the concept (UC)	Incorrect	Yes, I am sure
3	Lack of understand the concept (LUC)	Incorrect	No, I am not sure
		Correct	No, I am not sure

Based on the conclusions from the reflections in cycle II, which had improved learning from cycle I, the researchers and observers agreed to cycle II. The results of observ-

ing the average student activity during learning activities during both cycles can be seen in the Table 4.

Table 4 indicates that the average student activity increased in each cycle, from 2.67 to 3.17 in a good category. This shows that the use of a problem-based learning model with the help of a virtual laboratory can increase student involvement in the learning process. Research which found that student activity in learning with the Problem-Based Learning (PBL) model has increased [15].



**Fig. 5.** Learning Implementation Graph

The graph illustrates the increase in the teacher's ability to carry out learning using a problem-based learning model from cycle I to cycle II, from cycle I to cycle II. It can be concluded that teachers are becoming increasingly skilled at managing learning using the PBL model, which is supported by a virtual laboratory.

Problem-Based Learning (PBL) is an educational method that connects academic content with practical, real-world situations, fostering the development of critical thinking and problem-solving abilities while also facilitating the acquisition of fundamental knowledge and concepts in the subject area. Prior studies have demonstrated that the PBL approach enhances students' ability to address and resolve challenges, thereby improving their problem-solving skills [16].

Based on the description above, it can be concluded that the application of a problem-based learning model assisted by virtual laboratory can increase the activity and learning outcomes of physics on the topic of light waves. A well-designed learning model can stimulate students' thoughts, feelings, attention, and motivation, thereby facilitating an effective learning process. The PBL model is the right choice for learning physics because physics material is directly related to problems in everyday life. Therefore, it is crucial to develop suitable teaching materials to facilitate the implementation of the PBL learning approach.

## 4 Conclusion

The Based on the results of research and data analysis on classroom action research (CAR) that has been carried out for 2 cycles, it can be concluded that the application

of a problem-based learning model assisted by a virtual laboratory can increase student learning outcomes in class XI IPA 1 SMA Negeri 1 Gorontalo on light waves. This model is also able to improve student learning activities in the good category, and the teacher's ability to carry out learning in the very good category. The suggestions resulting from this research are (1) Teachers need to master the use of problem-based learning models (PBL) to develop students' knowledge and encourage their motivation in seeking new knowledge; (2) It is important for a teacher to actively involve students in learning activities and provide fair opportunities to increase student involvement both individually and in groups; (3) Need support from the leadership of the education unit to encourage teachers to innovate in learning activities and the media used.

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