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Problem Based Learning (PBL) Assisted Virtual Laboratory: Effects on Improving Learning Motivation and Science Process Skills of Electricity for Vocational High School Students

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ABSTRACT

This research aims to increase students' motivation to learn physics through the application of the Problem Based Learning learning model. This research is considered very important because the results of the analysis of students' initial abilities through teacher and student respondents give low results. This research is a class action research (PTK) conducted in two cycles. The material in the first cycle is static electricity and dynamic electricity while the material in the second cycle is electromagnetic field. This research was conducted at SMKN 1 Tambang in Kampar Regency, Riau Province, with 19 students in class X of Machining Engineering, 16 males and 3 females. The steps in this PTK start from the pre-cycle stage (initial ability analysis), making learning tools and instruments, validating devices and instruments, taking action, evaluation, and reflection. The assessment of students' learning motivation and science process skills was carried out after the cycle ended which was assessed by the teacher himself through a learning motivation questionnaire totaling 35 items and student science process skills questions with a total of 18 multiple-choice questions. The average percentage of students' motivation to learn physics for cycle 1 was 68.30% in the medium category and in cycle 2 was 73.98% in the high category. Meanwhile, for the science process skills test, students in cycle 1 obtained results of 57.02% of the category were quite good and in cycle II, which was 77.48% of the high category. The increase in learning motivation can be seen from the change in the percentage of learning motivation questionnaires from the medium category to high and the change in science process skills can be seen from the change in test results from the fairly good category to good.

Keywords: *problem based learning learning model, learning media, learning motivation, science process skills*

INTRODUCTION

Education is outlined through learning. Learning is an interactive activity of various components to realize the achievement of learning goals. All of these components are interrelated, influence each other and achieve a goal (Suprayekti, 2003). These components include: objectives, materials, methods, and evaluations. The four learning components must be considered by teachers in choosing and determining what learning model will be used in learning activities (Rusman, 2012).

The learning approach used in the implementation of the 2013 curriculum is the scientific approach (Wijayanti, 2014). In this approach, teachers act as facilitators by guiding learning activities, providing feedback, explanations, and confirmation, while also supporting students in constructing knowledge. This aligns with the principles of Problem-Based Learning (PBL), where teachers play a crucial role in assisting students in solving real-world problems collaboratively.

Learning with a scientific approach fosters analytical, creative, and independent thinking skills (Machin, 2014), which are also core objectives of PBL.

Specifically in physics learning, the scientific approach encourages the development of scientific attitudes, thinking, and work skills through observing, questioning, experimenting, reasoning, and communicating (Pradipta, 2017). This emphasis on active engagement and interaction with the environment aligns with PBL's focus on student-centered exploration, enabling mastery of physics concepts through experiential activities (Masyhuri et al., 2017). Thus, the integration of the scientific approach and PBL supports the development of essential competencies in physics education.

The increase in student activity can be seen in the learning stages of Problem Based Learning. In the stage of organizing and guiding individual/group experiences, students discuss and exchange information between friends in the group (Dewi et al., 2016). According to (Ngalimun, 2012) Problem Based Learning is a learning model that trains and develops the ability to solve problems oriented to authentic problems from students' actual lives, to stimulate higher-level thinking skills.

However, despite the clear benefits of PBL, there are gaps in the existing literature regarding how this model specifically impacts motivation and science process skills. While studies have established the advantages of PBL in fostering critical thinking, there is limited exploration of how technological tools, such as virtual laboratories, interact with PBL to enhance these outcomes. Additionally, inconsistencies arise when comparing the effectiveness of PBL in different contexts or subjects, where some studies report significant improvements in student outcomes, while others show minimal impact. These discrepancies highlight the need for further investigation into the role of virtual laboratories in supporting PBL to maximize its potential benefits.

In addition to the learning model, innovations in learning media are also crucial in the educational process. Arsyad (2011) suggests that the use of learning media can stimulate learning activities and even have psychological effects on students. Kutluca (2010) highlights the importance of computer media in improving students' understanding of subject matter, noting its role as a facilitator in teacher learning. However, the integration of virtual laboratories with PBL remains underexplored. Virtual laboratories, defined as computer programs that simulate abstract phenomena or complex experiments found in real laboratories, offer potential to enhance student motivation and provide an interactive learning environment. This virtual tool could bridge the gap in current research by supporting problem-solving skills development and fostering a deeper understanding of scientific concepts, especially where traditional methods face limitations in engaging students. Thus, there is a need to investigate how combining Problem Based Learning with virtual laboratories can address these gaps and inconsistencies, further improving student motivation and science process skills.

Virtual Laboratory can be defined as a series of computer programs that can visualize abstract phenomena or complex experiments conducted in real laboratories so that they can increase learning motivation in an effort to develop the skills needed in problem-solving. This is in line with the opinion (Tatli & Alipasa, 2012) who said that the Virtual Laboratory is a supporting factor to enrich the experience and motivate students to conduct experiments interactively and develop experimental skills activities.

Motivation is a change in energy in a person that is characterized by the emergence of "feelings" and is preceded by a response to the existence of a goal (Sardiman, 2020). Students' learning motivation can be sourced from the motivation within the student which is called intrinsic motivation and can be sourced from the motivation that comes from outside the student called extrinsic motivation (Hamalik, 2011).

According to (Mudjiono, 2013) Learning motivation can be classified as low or high. If students' motivation to learn is high, students will show good learning attitudes and behaviors such as students showing high enthusiasm in carrying out learning activities, diligent and tenacious in carrying out learning activities even for a long time, and never getting tired let alone bored in learning. On the other hand, if students' motivation to learn is low, students will show bad learning attitudes and behaviors such as indifference in learning, learning activities are considered a burden and quickly tired and bored in learning (Nurhayati & Hadis, 2014).

Science process skills in learning Physics play an important role in the process of discovering and understanding concepts. Learning can be done through practicum or demonstration. Student involvement in practicum is able to force students to emerge and develop the potential of scientific science process skills in students, especially improving cognitive, psychomotor, and affective aspects. According to (Prihatiningtyas et al., 2013) knowledge of Physics, scientific concepts and ideas is obtained from a series of experiences carried out by constructing phenomena in them. The concept construction process is based on the process skills possessed by students. The higher the process skills possessed, the better the concept structure obtained, and the lower the process skills possessed, the narrower the conceptual structure obtained.

Process skills need to be developed and applied in the daily teaching and learning process. Four reasons why it should be developed according to (Conny, 1992) namely: (1) The development of science and technology is progressing faster so that it is no longer possible for teachers to teach concepts and facts to students; (2) There is a tendency that students better understand complex and abstract concepts if they are accompanied by concrete examples; (3) The discovery and development of science and technology is not 100% absolute but relative, (4) In the teaching and learning process, Concept development is inseparable from the development of attitudes and values in students.

METHODOLOGY

The subjects of this research were Grade X students of the Mechanical Engineering program at SMKN 1 Tambang, Kampar Regency, Riau. The Grade X Mechanical Engineering class consisted of 19 students, comprising 16 males and 3 females. This class was chosen based on the results of initial observations and analyses, which revealed low motivation to learn and poor science process skills among students in physics learning. The type of research is classroom action research which is carried out in 2 cycles. The stages in this PTK consist of four stages, namely planning, implementation, termination and reflection. Broadly speaking, it can be seen from figure 1.

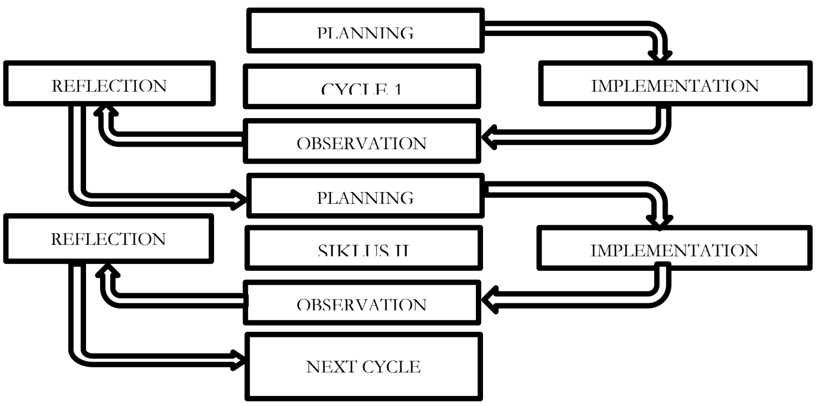

Figure 1. Kemmis & Mc Taggart's Action Research Model

The Kemmis and McTaggart Action Research Model consists of four cyclical stages. Planning, which is the preparation made for the implementation of Classroom Action Research, such as: preparing a Learning Implementation Plan and making learning media. Acting Implementation, which is a description of the action to be taken, the work scenario of the corrective action to be carried out and the procedure for the action to be implemented. Observation, This observation is carried out to see the implementation of all plans that have been made well, there are no irregularities that can provide less than optimal results in improving student learning outcomes. Observation activities can be carried out by providing observation sheets or in other ways that are in accordance with the data needed. Reflecting, which is an evaluation activity about the changes that occur or the results obtained on what has been collected as a form of impact of the actions that have been designed. Based on this step, the changes that have occurred will be known. How and to what extent the actions set are able to achieve significant change or overcome problems. Departing from this reflection, an improvement in action in the form of re-planning can also be made (Kemmis, S., & McTaggart, R, 2007).

The data collection technique is carried out by providing student learning motivation questionnaires and student science process skills tests. Validation results of the student physics learning motivation questionnaire sheets in Cycle I and Cycle II. The instrument validation was assessed based on three categories: the instruction aspect, the statement indicator aspect, and the language aspect. The validation results are summarized as shown in Table 1.

Table 1. Results of the Validation of Questionnaire for Students

No	Assessment Indicators	Cycle I		Cycle II	
		Average Score	Categori	Average Score	Categori
1	Instruction Aspect	4	SV	4	SV
2	Statement Indicator Aspect	3.50	SV	3,50	SV
3	Language Aspect	4	SV	4	SV
	Average	3,83	SV	3,83	SV

Table 1. presents the validation results of the student physics learning motivation questionnaire sheets, with an average score of 3.83 (highly valid) in both Cycle I and Cycle II. The "highly valid" category indicates that the questionnaire instrument is suitable for use in the research.

Next are the validation results of the student science process skills test instrument in Cycle I and Cycle II. The validation of the science process skills test questions was conducted before the learning process in Cycle I and Cycle II began to ensure the questions were suitable for use. The instrument validation was assessed based on three categories: the material aspect, the construct aspect, and the language aspect. The validation results are presented in Table 2.

Table 2. Results of the Validation of the Test Instrument for Students

No	Assessment Indicators	Cycle I		Cycle II	
		Average Score	Categori	Average Score	Categori
1	Material Aspect	3,29	V	3,43	V
2	Construct Aspect	3	V	3,5	SV
3	Language Aspect	3,50	SV	4	SV
	Average	3,26	V	3,64	SV

Based on Table 4.6, the average score for Cycle I is 3.26, categorized as valid, and the average score for Cycle II is 3.64, categorized as highly valid. These results indicate that the student science process skills test instrument meets the requirements and is suitable for use in the research. The component of student learning motivation consists of 4 aspects that can be seen in table 3.

Table 1. Components of Student Learning Motivation

No.	Aspects	Indicator
1.	*Attention*	Capture students' interests and stimulate students' curiosity to learn
2.	*Relevance*	Meet the student's personal needs/goals for positive attitude effects
3.	*Confidence*	Helps students have confidence/feel that students can succeed and control their success
4.	*Satisfaction*	Reinforce achievements with rewards (internal and external)

(Keller & Keller, 2010)

The student's basic physics science process skill test instrument consists of 6 indicators provides a blueprint for questions designed to assess students' basic science process skills. The table includes six skill indicators: observing, classifying, interpreting, measuring, concluding, and communicating, each with specific sub-indicators and a designated number of questions.

For the observing indicator, students are required to use their senses as observation tools, which is measured with three questions. The classifying indicator involves the ability to compare, identify differences or similarities, and connect observation results, also measured with three questions. Next, the interpreting indicator focuses on the ability to identify patterns from a series of observations, with three questions provided.

The measuring indicator covers the ability to classify and compare various objects in the surrounding environment, with three questions included. The concluding indicator requires students to determine the state of an object or event based on facts, concepts, and principles, also with three questions. Lastly, the communicating indicator assesses students' ability to read graphs, tables, or diagrams accurately and explain research or experimental results, with a total of three questions. This blueprint is designed to ensure that every aspect of basic science process skills is comprehensively assessed, providing a clear picture of students' competencies in science as seen in table 2.

Table 2. Basic Science Process Skills Indicators

KPS Aspects	Description
Observe	observing natural objects and phenomena with the five senses: sight, hearing, touch, smell and taste or taste.
Measure	Measuring is paramount in fostering quantitative observation, classifying and comparing everything around us, and communicating accurately and effectively to others;
Classification	selecting various event objects based on their special characteristics, so that a similar class or group of events is obtained from the event object in question;
Conclude	skills to decide the state of an object or event based on known facts, concepts, and principles.
Forecasting	make predictions about everything that will happen in the future, based on estimates on patterns, or certain intelligences or the difference between facts, concepts and principles in science;
Communicate	Describe or describe the empirical data of experiments/observations with graphs or tables or diagrams or change them in the form of one of them; compile and deliver reports systematically and clearly; explain the results of the experiment or investigation; reading graphs or tables or diagrams; discussing the results of activities of a problem/event

(Mudjiono, 2013)

Data on students' motivation to learn physics was obtained from a questionnaire and then analyzed by comparing the results of pre-cycle, cycle I and cycle II. The calculation in the study uses the formula:

$$P = \frac{f}{n}\ x\ 100\% \quad (1)$$

Where, *P* represents the percentage of students' motivation, *f* denotes the frequency or number of responses corresponding to a particular category, and *n* is the total number of response. The number of scores obtained by students for each cycle is included in the learning motivation category as shown in table 3.

Table 3. Criteria for Motivation for Learning Physics

Value (%)	Category
86 – 100	Very High
71 – 85	High
56 – 70	Medium
41 – 55	Low

Adaptation (Ramli, 2018)

The data on science process skills in this study were obtained from a written science process skill test to students. Data analysis was carried out by comparing data from Pre-Cycle, cycle I, and cycle II. The calculations in this study to calculate science process skills are:

$$Science\ Process\ Skills = \frac{Total\ Student\ Score}{Maximum\ Score} x100\% \quad (2)$$

Where, Total Student Score is represents the total score achieved by the student, and Maximum Score is the highest possible score for the assessment. This formula calculates the percentage of the student's performance in science process skills relative to the maximum possible score.

The criteria for the results of students' science process skills can be seen in table 4

Table 4. Science Process Skill Criteria

No.	Skill Level of Science Process (%)	Category
1.	81 - 100	Excellent
2.	61 – 80	Good
3.	41 - 60	Pretty Good
4.	21 – 40	Not Good
5.	0 – 20	Very Bad

Adaptation (Sari, 2019)

Students' physics learning motivation scores for each cycle will be analyzed per achievement indicator obtained. Cycle 1 static and dynamic electrical material consisting of 4 meetings. Cycle 2 is about the electromagnetic field which consists of 3 meetings. Students are considered to have good motivation to learn physics if they succeed in at least obtaining a motivation score in the high category range, while for the success of science process skills, students if they obtain a score of more than 75% in the good category.

RESULT AND DISCUSSION

Based on the researcher's analysis starting from pre-cycle, cycle I to cycle II, the researcher can see a comparison in each variable, namely students' motivation to learn physics, students' science process skills and students' learning activities. The comparison between the cycles can be seen in the following explanation:

Motivation for Learning Physics Students

The results of the comparison of students' motivation to learn physics in pre-cycle, cycle I and cycle II can be seen in figure 2

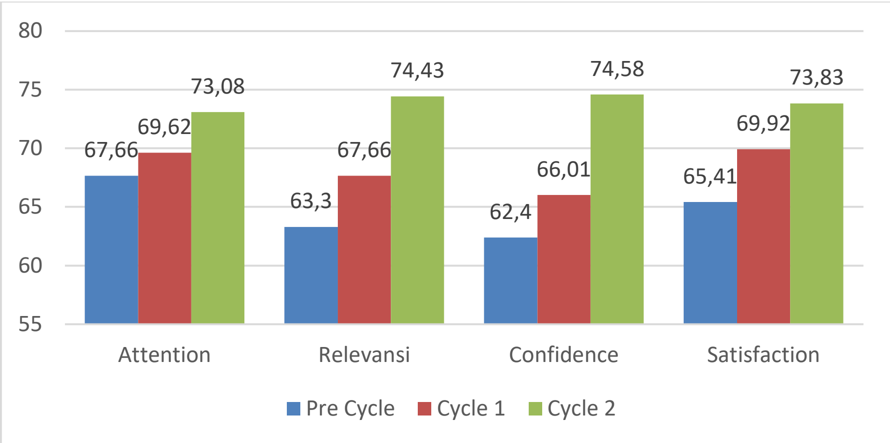

Figure 2. Comparison of Students' Motivation to Learn Physics

Figure 2 shows the comparison of students' motivation to learn physics between pre-cycle, cycle I and cycle II. The average percentage of students' motivation to learn physics in the pre-cycle was 64.69% with the medium category, in the first cycle it increased to 68.30% with the medium category and in the second cycle it increased again to 73.98% with the high category.

Based on the figure, the highest increase is in the confidence indicator. In cycle II, the researcher gave all students the opportunity to take turns conducting virtual simulation experiments at each meeting. This provides a new experience for every student. Not only in the practicum, students also write down the results of their observations in turn and appear for presentations in turn. Likewise for other groups, students ask questions and give opinions alternately in their groups. So that all students participate in the learning process from the beginning of the first meeting to the last meeting. This fosters a high sense of confidence for students. High confidence affects a person's motivation to learn and success in learning. This is in accordance with the opinion (Sardiman, 2020), Learning motivation as the overall driving force in students that gives rise to learning activities, which ensures the continuity of learning activities and provides direction to learning activities, so that the goals desired by the learning subject can be achieved. Learning motivation is defined as the driving force that triggers and sustains students' behavior, directing them toward a specific goal (Lei Zhang, 2023).

Students' Science Process Skills

The student science process skill test in cycle I was taken by the researcher on static electricity and dynamic electricity materials, while for the science process skill test of students in cycle II on electromagnetic field materials. A comparison of students' science process skills can be seen in figure 3

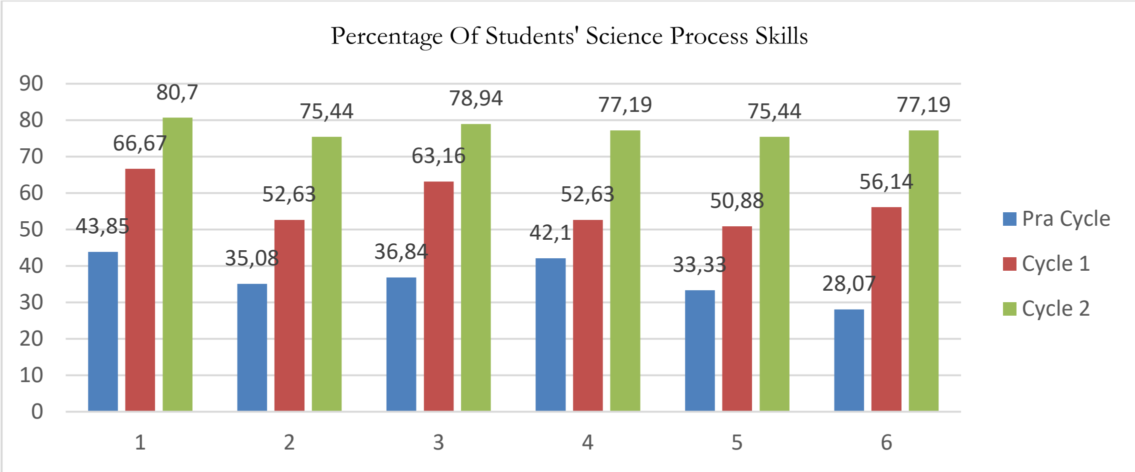

Figure 3. Comparison of Students' Motivation to Learn Physics

Describe: (1) Observe, (2) Measure, (3) Classify, (4) Conclude, (5) Forecasting (predicting), (6) Communicate.

Figure 3 shows a comparison of the results of students' science process skills starting from pre-cycle, cycle I to cycle II. The average result of the student science process skill test in the pre-cycle was 36.55% with the category of not good. In the first cycle, the average result of the student science process skills test was 57.02 with a fairly good category. As for the second cycle, the average result of the student science process skill test increased by 77.48% with the good category.

It can be seen that for indicator 1, namely observing (observation) occupies the highest results in cycle II. This happens because students are used to selecting relevant facts from the things observed and comparing things observed carefully in looking for similarities or differences in an object or event. It is proven that for the observation question, when analyzed from the 3 number of questions given, 19 students were able to answer 46 questions correctly. When averaged, the results obtained for the observing indicator are 80.7%.

The second indicator that experienced a significant increase was in the forecasting (predicting) indicator. In the first cycle, the results obtained were 50.88% (out of 3 questions given, 19 students answered 29 questions correctly and 28 questions answered incorrectly). However, in the second cycle, the score obtained reached 75.44% (out of 3 questions given, 19 students answered 43 questions correctly and 14 questions answered incorrectly). In this forecasting indicator, students begin to make estimates about something that has not yet happened based on facts that indicate an existing trend or pattern.

Science process skills are essential competencies that enable students to engage effectively with scientific concepts and develop a deeper understanding of the natural world. These skills include observing, drawing conclusions, experimenting, and analyzing data, which are crucial for understanding and applying scientific knowledge. Engku Mohd Sharul emphasizes their importance in helping students engage in practical learning activities and improve their comprehension of scientific concepts (Engku Mohd Sharul,2024)

Furthermore, science process skills are foundational for conducting and interpreting scientific research. According to (Rismawati et al., 2024), these skills help students develop a systematic approach to problem-solving and enable them to understand scientific investigations effectively. Sholihah highlights their significance in applying scientific concepts to real-life situations, fostering critical thinking and decision-making abilities that are essential for addressing everyday challenges (Sholihah, 2024).

In addition, science process skills are instrumental in developing students' cognitive abilities. Anggrella and Sudrajat (2024) argue that these skills serve as a foundation for critical thinking and problem-solving, encouraging students to think systematically. Further stress the importance of these skills in analyzing and interpreting data, which enhances students' understanding of scientific concepts (Listiani and Kusuma, 2024). Overall, these skills are vital not only for academic success but also for preparing students to navigate real-world challenges with a scientific perspective.

CONCLUSION

Every aspect of the student's physics learning motivation indicator by applying the Problem Based Learning model assisted by the virtual lab has improved from the previous cycle. Students are no longer shy to make presentations, ask questions and give opinions in discussions. The Problem Based Learning model is able to increase student learning motivation. Likewise, after the improvement in cycle II, there was a positive impact on student learning motivation. In the first cycle, an average of 143.35 was obtained, and in the second cycle, an average of 152.19 was obtained, which was in the high category. The results obtained show that the application of the Problem Based Learning model can foster students' enthusiasm or motivation to learn. Overall, each indicator of students' science process skills by applying the Problem Based Learning model assisted by virtual labs has improved from the previous cycle. This is in line with the opinion concluded that the Problem Based Learning model has an effect on students' science process skills. The results of the analysis based on the research obtained the average percentage of the experimental group was higher than that of the control group. This is in line with his research which concluded that the application of the Problem Based Learning model was able to increase the average score of students' science process skills. Based on the conclusion, it can be determined that in this study, learning using the Problem Based Learning model can improve students' motivation and the average score of their science process skills**.**

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