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Problem-Based Learning Model in Real Physics Experiments to Increase Learning Outcomes and Science Process Skills of Science Teacher Candidates

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Abstrak

Model pembelajaran berbasis masalah cocok digunakan dalam pembelajaran fisika. Penelitian ini bertujuan untuk meningkatkan hasil belajar dan keterampilan proses sains mahasiswa melalui implementasi model pembelajaran berbasis masalah dalam eksperimen riil fısıka. Penelitian ini merupakan penelitian tindakan kelas. Subjek penelitian ini adalah 15 mahasiswa calon guru IPA di Universitas Negeri Manado yang mengontrak mata kuliah Fisika Dasar I. Teknik pengumpulan data menggunakan teknik tes dan observasi. Instrumen penelitian yang digunakan adalah tes hasil belajar dan lembar pengamatan. Teknik analisis data dilakukan secara kuantitatif dan deskriptif kualitatif. Hasil analisis data menunjukkan bahwa (1) hasil belajar mahasiswa pada siklus I sebesar 2,66 meningkat menjadi 3,20 pada siklus II, dan (2) kemampuan keterampilan proses sains mahasiswa pada siklus I sebesar 2,55 meningkat menjadi 3,18 pada siklus II. Dengan demikian, implementasi model pembelajaran berbasis masalah dalam eksperimen riil fısıka berhasil meningkatkan hasil belajar dan keterampilan proses sains mahasiswa.

Kata Kunci: *Pembelajaran Berbasis Masalah, Eksperimen Riil, Fisika*

Abstract

The problem-based learning model is suitable for use in physics learning. This study aims to increase student learning outcomes and science process skills by implementing problem-based learning in real physics experiments. This research is classroom action research. The subjects of this study were 15 science teacher candidates at Universitas Negeri Manado who contracted for Basic Physics I courses. Data collection techniques are used to test and observe techniques. The research instruments used were learning achievement tests and observation sheets. We carried out data analysis techniques quantitatively and qualitatively descriptive. The results of the data analysis show that (1) student learning outcomes in cycle I increased by 2.66 to 3.20 in cycle II, and (2) students' science process skills in cycle I increased by 2.55 to 3.18 in cycle II. Thus, the implementation of the real physics experimental problem-based learning model succeeded in increasing student learning outcomes and science process skills.

Keywords: *Problem-Based Learning, Real Experiments, Physics*

INTRODUCTION

Knowledge is not acquired passively by someone but through action to learn (Martini, 2017). Learning is a process of intentional behavior change based on the experience of the attitudes, values, knowledge, and skills mastered (Setiawati, 2018). Learning aims to make students live up to the accepted scientific concepts. Learning in the view of cognitive development theory states that children's cognitive development depends on how far they actively manipulate and interact with their environment (Gottlieb & Oudeyer, 2018). From Piaget's view of the stages of children's cognitive development, it can be understood that at certain stages, the ways and abilities of children construct knowledge vary based on the child's intellectual maturity (Ismail, 2020). In this theory, students are required to have the skills to adapt.

As a fundamental, physics can be considered a science that seeks to describe and explain laws and natural events with a picture according to human thought. Studying science can be a way for humans to understand natural phenomena that occur around them (Suriani, Wola, & Komansilan, 2022). Physics is one of the basic sciences, as are the subjects of chemistry, biology, astronomy, and geology. Sari, Sunarno, & Sarwato (2018) stated that physics is a science that studies natural events that are physical and can be learned through observation, experimentation, and theory. Thus, it can be concluded that physics is part of the natural sciences and can be classified into two parts, namely (1) the physical sciences whose objects study, for example, matter and energy, and the transformation of matter and energy, and (2) the biological sciences that study living things and their environment.

Studying physics aims to enable students to master physics concepts, principles, and laws. It is hoped that students will be able to rearrange them in their language according to their level of maturity and intellectual development (Novita, 2020). Physics is developed through the ability to think analytically, inductively, and deductively in solving problems related to surrounding natural events, both qualitatively and quantitatively (Armandita, 2017). Physics must be understood in a way that allows it to be used in solving problems (Nurdin, 2017). Learning physics requires relatively high intellect, so most students have difficulty learning it (Rahmawaty, 2022).

To change the notion that learning physics which is difficult to understand becomes something fun, based on Kermendikbud No. 65 of 2013 concerning Process Standards for Elementary and Secondary Education, has hinted at the need for a guided learning process by the principles of a scientific/scientific approach. Efforts to apply physics concepts to the real world test students' abilities to apply the knowledge they master to the world around them. It is because students who study science are expected to be able to apply the science concepts they have learned in everyday life (Wola, Ibrahim, & Purnomo, 2020).

The learning process can be carried out by conducting real experiments directly in the laboratory and indirectly through virtual laboratories. Experimental activities are one of the factors that support physics learning activities (Putri, Sarwi, & Akhlis, 2018). Experiment with practicum activities to help students understand the scientific process (Tulandi & Rondonuwu, 2019). In experimental activities, student learning activities are more clearly visible. Students can be more actively involved in the learning process throughout the stages of preparing activities and carrying out experimental activities. Real experiments involve a real physical investigation process (Hikmawati, Kosim, & Sutrio, 2020).

The learning model can be interpreted as a conceptual framework that describes a systematic procedure for organizing learning experiences to achieve certain learning goals and serves as a guide for learning designers and teachers in planning and carrying out learning activities (Tibahary & Muliana, 2018). One good learning model to use in learning physics is the problem-based learning model. Darwati & Purana (2021) state that the model of problem-based learning is one way that educators can use an effort to help students to be competent in solving problems and face the challenges ahead. Problem-based learning stimulates thinking levels high in problem-oriented situations, including how the students learn (Sucipto, 2017). Problem-based learning focuses on student-centered learning by exposing students to unstructured problems to encourage them to collaborate in building their knowledge (Agnesa & Rahmadana, 2022). Problem-based learning is a learning model characterized by real problems involving students being able to find a problem that will be studied in learning and solve the problems they face through the stages of scientific thinking (Tanti & Muljani, 2022).

In problem-based learning, learning is initiated by problems, questions, or puzzles that students will solve independently (Agustina, 2018). The problem-based learning model is based on constructivism theory, defined as generative learning, creating something meaningful from what is learned (Fatimah, Abustang, & Amaliyah, 2022). Constructivism views learning as a human activity to build or create knowledge by giving meaning to their knowledge according to their experience (Ekawati, 2019). The importance of actively building one's knowledge occurs through mutual influence between previous and recent learning. In other words, a person actively builds knowledge by comparing new information with his existing understanding. When this condition occurs, the student's initial knowledge can usually be different from the scientific knowledge that has just been received, so a sense of imbalance arises within him/her. Urfany, Afifah, & Nuryani (2020) stated that imbalance is the main motivational factor for learning if a student realizes that his ideas are inconsistent with scientific knowledge. On the other hand, Gani, Tumewu, & Wola (2022) revealed that student motivation is important because motivated students will be serious and interested in learning and get satisfying learning results.

Based on interviews with lecturers of Basic Physics I at the Department of Science Education, Universitas Negeri Manado, it is known that the Mechanics topic is the most difficult topic for students to understand. It can be seen from the quiz scores for the last three years, where an average of 71% of students did not achieve a score of 3.00. The lecturer also stated that he had never used a problem-based learning model on this mechanics topic. Furthermore, lecturers have not orientated learning that trains science process skills, so students are not trained to use science process skills in learning physics. Even learning physics using the process skills approach through the experimental method will impact students' efforts to learn and understand physics concepts (Londonaung & Rondonuwu, 2021). The conditions of the problems that researchers encountered need special attention to be corrected, considering that these students will become science teachers in the future. One solution to these problems is to use a learning model appropriate to the physics topic. The learning model must also be able to make students actively involved in learning activities (Widiastuti, 2022). Yew & Goh (2016) stated that more in-depth research is needed to examine the effect of problem-based learning on student learning outcomes and skills in academic situations. Based on what the researchers have stated before, this research aims to increase student learning outcomes and science process skills through the implementation of problem-based learning in real physics experiments.

METHODOLOGY

This research is classroom action research. The research design refers to the Kemmis & McTaggart (1988) model, which consists of four stages, namely planning, implementing, observing, and reflecting in a spiral system that is interrelated. The subjects of this study were 15 students in the Department of Science Education, Universitas Negeri Manado, who contracted for the Basic Physics I course. The research was conducted in August-September 2022, in the odd semester of the 2022/2023 school year. Data collection techniques using test and observation techniques. Written tests are carried out to obtain data about student learning outcomes which are carried out at the end of each cycle. Observations were made to obtain data about the ability of students' science process skills. Observations were carried out by researchers assisted by observers using observation sheets prepared by researchers.

The research instruments used were learning achievement tests to assess cognitive learning outcomes and observation sheets to assess science process skills. Data analysis techniques were carried out quantitatively and qualitatively descriptive. Quantitative analysis is carried out by calculating a score of learning outcomes and a score of science process skills ability. The qualitative descriptive analysis consists of data reduction, exposure, and conclusion.

Data analysis regarding learning outcomes is carried out by calculating the score of the test results with the following equation:

$$\text{Learning outcomes} = \frac{\text{score obtained}}{\text{max score}} \times 100\% \quad (1)$$

The scores that have been obtained are then interpreted into learning outcomes categories by adapting the value conversion reference in Peraturan

Rektor Universitas Negeri Manado No. 9 Tahun 2021 tentang penyelanggaraan pendidikan di Universitas Negeri Manado as shown in Table 1.

Table 1. Categories of Learning Outcomes

Score Range	**Grade**	**Category**
3.60 – 4.00	A	Very high
2.75 – 3.59	B	High
2.00 – 2.74	C	Moderate
1.00 – 1.99	D	Low
0.00 – 0.99	E	Very low

Data analysis on students' science process skills is carried out by calculating the score of the test results with the following equation:

$$\text{Science process skills} = \frac{\text{score obtained}}{\text{max score}} \times 100\% \quad (2)$$

The scores that have been obtained are then interpreted into the category of science process skills (Haryanto et al., 2019), as shown in Table 2.

Table 2. Categories of Science Process Skills

Score Range	**Category**
3.50 – 4.00	Excellent
2.75 – 3.49	High
1.75 – 2.74	Low
1.00 – 1.74	Poor

Data analysis, according to Miles & Huberman (1992), namely reducing data, presenting and drawing conclusions. First, data reduction is carried out, meaning summarizing, choosing the main things, and focusing on the important things. So, in this case, the data is reduced to students who are actively involved in the learning process. Second, presenting the data is done in a brief description. Third, drawing conclusions and verification.

RESULT AND DISCUSSION

Learning Cycle I

The activity at the planning stage is to create learning scenarios in the form of semester learning plans (RPS) as guidelines for implementing learning on the topic of Mechanics. In addition, researchers also prepared assessment instruments for learning outcomes tests, compiled observation sheets to assess science process skills, and student worksheets. Researchers also prepared the learning resources in the form of course modules to be distributed to students via the *WhatsApp Group*. Furthermore, the researcher gave instructions regarding modules and student worksheets so that learning ran smoothly and the results of observations could be used as material for reflection. Execution is an implementation activity of a previously designed lesson plan. Lectures at the first meeting were held on August 24, 2022, while lectures at the second on August 31, 2022. Observations were made during the lecture process. Student learning outcomes are assessed after completing cycle I, while science process skills are assessed during the cycle I. Research data on learning outcomes in cycle I can be seen in Table 3, while science process skills can be seen in Table 4.

Table 3. Learning Outcomes of Cycle I

Student Code	Score	Category	Description
M01	2.40	Moderate	Not Completed
M02	2.60	Moderate	Not Completed
M03	3,12	High	Complete
M04	2.60	Moderate	Not Completed
M05	2.60	Moderate	Not Completed
M06	2.60	Moderate	Not Completed
M07	2.60	Moderate	Not Completed
M08	2.60	Moderate	Not Completed
M09	2.80	High	Complete
M10	2.60	Moderate	Not Completed
M11	3.00	High	Complete
M12	2.80	High	Complete
M13	2.40	Moderate	Not Completed
M14	2.80	High	Complete
M15	2.40	Moderate	Not Completed
Average	2.66	Moderate	Not Completed
Complete	33%		
Not Completed	67%		

The value of student learning outcomes is obtained from the results of written tests with the type of description questions. Table 3 shows that the learning outcomes in cycle I were only 33% of the total students who completed, while 67% did not. These results indicate that the learning outcomes in cycle I still need to fulfill the classical learning mastery requirements if at least 70% of the total students achieve a minimum score of 2.75 (B).

Table 4. The Ability of Science Process Skills Cycle I

Student Code	Score	Category
M01	2.40	Low
M02	2.30	Low
M03	3.00	High
M04	2.30	Low
M05	2.40	Low
M06	2.70	Low
M07	2.50	Low
M08	2.40	Low
M09	2.70	Low
M10	2.20	Low
M11	2.80	High
M12	2.70	Low
M13	2.40	Low
M14	2.70	Low
M15	2.70	Low
Average	2.55	Low

Data regarding students' science process skills were obtained from observations during the first cycle of learning activities. Table 4 shows that the average score of students' science process skills in cycle I of 2.55 is still relatively low. These results indicate that students' science process skills in cycle I are not optimal and need to be increased.

Learning Cycle II

The learning process in cycle II was carried out as an improvement from the action in cycle I. Reflection in cycle I provided information that student learning outcomes did not meet the completeness requirements and the ability of students' science process skills still needed to be increased. This condition then becomes the basis for the implementation of cycle II. The implementation of cycle II was similar to cycle I, where the first meeting was held on September 7, 2022, face to face, while the lectures at meeting II were held on September 14, 2022.

Based on observations made in cycle II, data on learning outcomes was obtained, as shown in Table 5, and data on students' science process skills, as shown in Table 6.

Table 5. Learning Outcomes of Cycle II

Student Code	Score	Category	Description
M01	3.00	High	Complete
M02	2.80	High	Complete
M03	3.60	Very high	Complete
M04	3,12	High	Complete
M05	3.00	High	Complete
M06	3,32	High	Complete
M07	3,28	High	Complete
M08	2.80	High	Complete
M09	3,40	High	Complete
M10	3,12	High	Complete
M11	3.52	High	Complete
M12	3.52	High	Complete
M13	3,32	High	Complete
M14	3,40	High	Complete
M15	2.80	High	Complete
Average	3.20	High	Complete
Complete	100%		
Not Completed	0%		

The value of student learning outcomes is obtained from the results of written tests with the type of description questions. Table 5 shows that the learning outcomes in cycle II have achieved 100% completeness of the total students with an average score of 3.20. These results indicate that the learning outcomes in cycle II have fulfilled the classical learning mastery requirements because more than 70% of the total students achieved a minimum score of 2.75 (B).

Table 6. The ability of Science Process Skills Cycle II

Student Code	Score	Category
M01	3.00	High
M02	2.80	High
M03	3,40	High
M04	3.20	High
M05	3.00	High
M06	3,40	High
M07	3,40	High
M08	3.20	High
M09	3.50	Excellent

Student Code	Score	Category
M10	3.20	High
M11	3.20	High
M12	3,40	High
M13	3.00	High
M14	3.00	High
M15	3.00	High
Average	3,18	High

Data regarding students' science process skills were obtained from observations during cycle II learning activities. Table 6 shows that the average score of students' science process skills in cycle II is 3.18 and is classified as high. These results indicate that students' science process skills in cycle II are good.

The research that has been carried out aims to increase learning outcomes and students' science process skills by implementing problem-based learning in real physics experiments. Real experiments are experimental activities using real tools and materials (Putri et al., 2018). Thus, the problem-based learning model based on real experiments is problem-based learning carried out through experimental activities using real tools and materials. The data in this study were obtained through a learning achievement test instrument to measure students' cognitive learning outcomes and observation sheets to assess students' science process skills.

The results of observations in the form of assessments during lectures in cycle I showed that the average score of all student learning outcomes, namely 2.66, was still in the incomplete category. M03 is a student with the highest score, namely 3.12, while M01, M13, and M15 are students with the lowest score, namely 2.40. Furthermore, it is known that only 33% of students complete, so they need to meet the minimum learning completeness criteria, namely 70% of the total students. In addition, an assessment of students' science process skills showed that the average score of all students was 2.55 and was still in the low category. M03 has the highest science process skills score of 3.00, while M10 has the lowest score of 2.10. The results of observations in this cycle indicate that improvement is still needed as best as possible in the next learning cycle.

The results of observations in the form of assessments during lectures in cycle II showed an increase in student learning outcomes scores from 2.66 with a percentage of 33% completeness in cycle I to 3.20 with a percentage of 100% completeness in cycle II. Thus, the acquisition of the average score indicates that students' cognitive learning outcomes have fulfilled the minimum learning mastery criteria of 70% of the total students. Student learning outcomes in the first cycle are in the moderate category, while in the second cycle, there is an increase so that they are included in the high category. The ability of students' science process skills also increased, were in cycle I still in the low category, while in cycle II, included in the high category.

The implementation of the problem-based learning model in real physics experiments shows an increase in student learning outcomes from cycle I to cycle II. Data analysis shows that student learning outcomes have increased by 33%. Based on the research results, it is clear that the problem-based learning model in real physics experiments can increase student learning outcomes. It is in accordance with the results of research by Jauhariyah (2017) showing that the Application of Problem Based Learning in Physics II Curriculum Study Lectures can increase student learning outcomes. Research by Priyono et al. (2018) also proves that applying a problem-based learning model can increase student learning outcomes in engineering physics courses.

In addition, implementing the problem-based learning model in real physics experiments also increased students' science process skills from cycle I to cycle II. It can be seen clearly from the average score of students' science process skills in cycle I of 2.55, which is still relatively low and then increased to 3.18, classified as high in cycle II. Based on the research results obtained, it is clear that the problem-based learning model in real physics experiments can increase students' science process skills. Research by Duda, Susilo, & Newcombe (2019) shows the same achievement, where the problem-based learning model through practicum can increase students' science process skills.

The implementation of the problem-based learning model has proven to be suitable for use in real physics experiments. It is because the problem-based learning model has characteristics, namely: (a) using problems at the beginning of the learning process, (b) enabling collaborative learning in small groups, (c) student-centered learning, (d) the role of the supervisor as a tutor, and (e) provide plenty of time for students to study independently (Wijnia, Loyens, & Rikers, 2019). Bodagh et al. (2017) stated that problem-based learning represents a shift from the traditional lecture-based didactic approach to a student-centered approach. Problem-based learning as a pedagogical strategy appeals to many educators because it offers an instructional framework that supports active and group learning. It is because problem-based learning is based on the belief that effective learning occurs when students construct and jointly build ideas through social interaction and independent learning (Yew & Goh, 2016).

CONCLUSION

Based on the research that has been done, the researchers concluded that the implementation of the real physics problem-based learning experiment model succeeded in increasing student learning outcomes and science process skills. The suggestions that researchers can give are that further research can focus on differences in student learning outcomes and science process skills by implementing real experiments and virtual experiments in learning physics.

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