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THE EFFECTIVENESS OF PROBLEM-BASED LEARNING MODELS USING A STEAM APPROACH TO IMPROVE STUDENTS' MATHEMATICAL MODELING ABILITY ON STATIC ELECTRICITY MATERIALS

Helsi Hardiana[a*], Stepanus Sahala Sitompul[b], Hamdani[c]
Email: f1051201002@student.untan.ac.id

[a*, b, c] *Universitas Tanjungpura, Pontianak, Indonesia*

Abstract
This study aims to determine the effectiveness of the PBL model with the STEAM approach to improving students' mathematical modeling ability (MMA) on static electricity material at SMP Negeri 2 Pontianak. This form of research is a pre-experimental design type one-group pretest-posttest design. The research sample was class IXB students at SMP Negeri 2 Pontianak (32 people), with a cluster random sampling technique. The instruments used are tests and questionnaires. Based on the results of the Wilcoxon Test, Asymp values. Sig (2-tailed) of 0.000 (z< 0.05) shows that there are differences in the mathematical modeling ability of students in the pretest and posttest, with the level of effectiveness being in the very high category (d = 5.49). Based on response questionnaire data, 97% of students responded well to treatment, and 3% were in a suitable category. The study's conclusion is applying the PBL model with a practical STEAM approach to improving the mathematical modeling ability of students on static electricity material at SMP Negeri 2 Pontianak.

Keywords: PBL, STEAM, mathematical modeling, effectiveness, static electricity

Abstrak
Penelitian ini bertujuan untuk mengetahui keefektivitasan model PBL dengan pendekatan STEAM terhadap peningkatan kemampuan pemodelan matematis (KPM) peserta didik pada materi listrik statis di SMP Negeri 2 Pontianak. Bentuk penelitian ini yaitu *pre-experimental design* jenis *one-group pretest-posttest design.* Sampel penelitian yakni peserta didik kelas IXB di SMP Negeri 2 Pontianak (32 orang), dengan teknik sampling *cluster random sampling.* Instrumen yang digunakan adalah tes dan angket. Berdasarkan hasil Uji Wilcoxon nilai *Asymp. Sig* (2-*Tailed*) sebesar 0.000 (z< 0.05) hal ini menunjukkan bahwa terdapat perbedaan kemampuan pemodelan matematis peserta didik pada pretest dan posttest, dengan tingkat kefektivitasan berada pada kategori sangat tinggi (*d* = 5,46). Berdasarkan data angket respon sebanyak 97% peserta didik memberikan respon yang sangat baik terhadap perlakuan, dan 3% berkategori baik. Kesimpulan penelitian yakni penerapan model PBL dengan pendekatan STEAM efektif untuk meningkatkan kemampuan pemodelan matematis peserta didik pada materi listrik statis di SMP Negeri 2 Pontianak.

Kata Kunci: PBL, STEAM, pemodelan matematis, efektivitas, listrik statis

INTRODUCTION

21st-century education requires teachers to change their views on the learning process (Liu, 2022). The learning process initially focused on subjects, then became focused on students, from teaching knowledge to teaching students to learn, from focusing on conclusions to focusing on processes (Liu, 2022). Apart from that, teachers must also organize a learning process that can guarantee that students have 21st-century skills (Andrian & Rusman, 2019). One of the 21st-century skills that students must have is thinking critically and solving problems (critical thinking and problem-solving skills) (Jayadi et al., 2020).

Students' problem-solving abilities are still relatively low (Mariani & Susanti, 2019). The learning process is still teacher-centered (Sakinah et al., 2020). As well as inappropriate learning models in the learning process (Ariska et al., 2019). Therefore, to overcome this problem, teachers must design learning that focuses on forming problem-solving skills in students using a problem-based learning process (Sakinah et al., 2020). According to Michael Atiyah, in the 21st century, there will be a strong relationship between mathematics and physics (Michelsen, 2015). An example of the relationship between mathematics and physics is to represent physics concepts in the form of a mathematical model (Suswati et al., 2020), and the process is called mathematical modeling (Kumala Sari, 2020).

Teachers in other countries worldwide are also facing the challenges of teaching mathematical modeling skills (Riyanto et al., 2019). Mathematical modeling can train problem-solving abilities and 21st-century abilities in students, such as collaboration, communication, critical thinking, creativity, and High-Order Thinking Skills (HOTS) (Riyanto et al., 2019).

Mathematical modeling is important in physics (Retnawati et al., 2018). The first important role is that mathematical modeling is used to solve physics problems and can even precisely predict systems in physics (Retnawati et al., 2018). Then, another role, namely, mathematical modeling, can support the learning process and help translate a real problem into a mathematical model (Nurjumiati et al., 2022). Therefore, mathematical modeling skills are one of the basic science skills that students must have because they have mathematical modeling skills, making studying them easier (Kabil, 2015). Even in more detail, Redish (2017) explains that the primary goal of physics is to create mathematical models that make it possible to predict and explain physical phenomena.

Mathematical modeling does have an essential role in physics, but mathematical modeling is also a fundamental problem in physics education (Kabil, 2015). The reason is that teachers tend to concentrate only on mathematical calculations rather than scientific concepts and do not help students understand the symbols used in physics, causing students to be unable to understand the meaning behind the physics equations (Kabil, 2015). Apart from that, when teaching physics, teachers often make it seem like physics only contains mathematical formulas that students must memorize. So, students think physics is just a manifestation of various abstract equations and formulas. Each symbol in a physics equation represents a physics concept and has a specific meaning (Kabil, 2015).

The discussion regarding the low mathematical modeling abilities of students in studying physics has been proven by several research results. Edward F. Redish, in his research entitled "Analysing the Competency of Mathematical Modeling in Physics," in 2017, explained that "These students treated physics as a pure math problem" (Redish, 2017), which means that students treated physics like a mathematics problem pure. The use of mathematics by physicists in physics is different from the use of mathematics by mathematicians in mathematics (Redish & Kuo, 2015). This is in line with the results of other research regarding students' low mathematical modeling abilities, namely, According to Nurjumiati & Yulianci (2019), students' mathematical modeling abilities and understanding of the symbolic language of physics still need to be improved. Putri, Firdaus, and Angraeni (2018) stated that students need help understanding the symbols used in physics equations, even though the mathematical symbols used in physics are beneficial in communicating complex ideas into simpler ones.

Based on the results of the literature review that the researchers conducted, references found that the learning model that can train students' mathematical modeling skills is the PBL model (Sakinah et al., 2020). The PBL model focuses on problems linked to physics concepts so that students can learn physics concepts and scientific problem-solving methods (Sakinah et al., 2020). In problem-based learning, students are focused on the problem so that they can better understand the problem. Finally, with a good understanding, students can model the problem mathematically (Sakinah et al., 2020). Applying the PBL model in mathematics learning has been proven to improve mathematical modeling abilities (Sakinah et al., 2020). So, it is not impossible for the PBL model to improve students' mathematical modeling abilities in physics learning.

The Problem-Based Learning (PBL) model is also a problem-based learning model that applies elements of 21st-century learning in the learning stages (Miyarso, 2019). By applying elements of 21st-century learning, this learning model can prepare students to think critically and analytically (Prayogi & Estetika, 2019) and increase students' problem-solving abilities in physics subjects by 88% (Firmansyah et al., 2022).

The learning approach that can be integrated into the PBL model is the Science, Technology, Engineering, Art, and Mathematics (STEAM) approach (Angga, 2022). Integrating the STEAM approach into the PBL model can increase students' interest in learning and their abilities in mathematics and science, making it easier for students to understand the material they study in the learning process (Suwono et al., (Angga, 2022). The STEAM approach can improve mathematics and science abilities and train students' 21st-century skills (Astutik & Hariyati, 2021).

This approach is also an approach that can teach students mathematical modeling skills, namely the STEAM approach (Liu, 2022). The STEAM approach will support students' formation of 21st-century skills and help improve science and mathematics abilities. According to Liu (2022), applying the STEAM approach can help students understand concepts and terms in learning. It can highlight mathematical characteristics in learning material while remembering students' engineering design thinking development. The STEAM approach can also train students' mathematical modeling skills and influence students' learning processes, technical skills, mathematical competencies, and creative thinking abilities (Viet et al., 2020). Mathematical modeling plays a vital role in solving physics problems. Therefore, research was conducted on the effectiveness of the problem-based learning model with the STEAM approach to improve students' mathematical modeling abilities on static electricity material.

METHOD

This research uses an experimental method in the form of a pre-experimental design, one-group pretest-posttest design research type. The research sample was 32 students in class IXB of SMP Negeri 2 Pontianak. The research design is in Table 1.

Table 1. One-Group Pretest-Posttest Design Research Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2

(Source: Sugiyono, 2019)

The research instruments used in this research were MMA test questions and student response questionnaires. Experts validated the instruments used in this research, which involved two lecturers and one science teacher. After validation, the results were obtained that the instrument was very valid. The next step is to carry out the test phase of questions. Testing questions aim to determine whether the problem-solving test instrument will be used is reliable. So, the research instrument used in this research has been tested for validity and reliability.

The stages of analyzing MMA scores in the pretest and posttest are as follows: (1) Statistical test to find out whether there is a difference in MMA scores between pretest and posttest with the help of (2) testing the effectiveness of treatment using effect size, (3) analyzing student responses to the process learning based on the results of the questionnaire that has been given. To determine whether there is a difference in students' MMA scores between the pretest and posttest, the dependent 2-sample t-test or Wilcoxon test is used (Sugiyono, 2021). The t-test is used if the MMA score data in the pretest and post-test meets the analysis requirements, and the Wilcoxon test is used if the problem-solving score data does not meet the analysis requirements. TeTheata was tested in this study using the SPSS 25 application. To determine the effectiveness of the treatment, the researchers used the effect size test (Widyastuti & Airlanda, 2021). The effect size test formula is as equation 1. The effect size criteria are in Table 2.

$$d = \frac{\bar{x}_{post} - \bar{x}_{pre}}{\sqrt{\frac{S^2{}_{pre} + S^2{}_{post}}{2}}} \quad (1)$$

Table 2. Effect Size Criteria

N-Gain	Criteria
$0 < d \leq 0,2$	Low
$0,2 < d \leq 0,5$	Medium
$0,5 < d \leq 0,8$	High
$d > 0,8$	Very High

(Widyastuti & Airlanda, 2021)

The response questionnaire used in the research consists of 15 statement items, which are described in terms of response indicators, namely relevance indicators and reaction indicators (Kusuma et al., 2017). Reaction indicators are divided into three aspects, namely (1) attention, (2) satisfaction, and (3) self-confidence. The questionnaire consists of 5 levels of answers, namely strongly agree (SS), (2) agree (S), unsure (RR), disagree (TS), and strongly disagree (STS). Table 3 is used as a reference for determining response categories. Then, the number of responses in each category is expressed as a percentage using the equation below (Arikunto, 2018)

$$P = \frac{F}{n} \times 100\% \quad (2)$$

Table 3. Response Score Categories

Score Interval	Category
$X > 55$	Very good
$45 < X \leq 55$	Good
$35 < X \leq 45$	Bad
$X \leq 35$	Very bad

(Source: Azwar, 2012)

RESULTS AND DISCUSSION

The Wilcoxon test determines whether there is a difference in students' MMA scores on the pretest and posttest. This is because students' MMA score data is not normally distributed. The Wilcoxon test results are in Table 4

Table 4. Wilcoxon Test Results

Tes Statistics	
	Posttest-Pretest
Z	-4.940[b]
Asymp. Sig.(2-Tailed)	.000

Table 4 shows that Asymp.Sig is 0.000. Asym Value. Sig. (2-tailed) in the calculation results is smaller than 0.05 (0.000<0.005). So, based on the results of these calculations, Ho is rejected, and Ha is accepted, resulting in the conclusion that there are differences in mathematical modeling abilities before and after applying the Problem-Based Learning model with the STEAM approach. This proves that applying the Problem-Based Learning model with the STEAM approach can improve students' mathematical modeling abilities. The results of this research are similar to the results of research conducted by Sakinah et al. (2020) that the PBL model is proven to be able to improve students' mathematical modeling abilities in three variable linear equations (SPLTV) material in class 10 of SMA Negeri 2

Palembang and also the results of research conducted carried out by Viet Cuong, Hong Quang, & Trung Tinh (2020) the STEAM approach can train students' mathematical modeling skills. So based on this, this research will strengthen previous findings and prove the truth of previous findings that the Problem-Base Learning model with the STEAM approach can improve mathematical modeling abilities.

Based on the statistical analysis that has been carried out, the problem-based learning model has proven to be effective in improving students' mathematical modeling abilities, with a very high effectiveness category. This is shown by the effect size score of 5.49. These findings also follow the results of research from Dibyantini and Azaria (2020) that the PBL model can improve students' mathematical modeling abilities in learning chemistry in buffer solution material with effectiveness in the medium category. The research findings conducted by this researcher show a higher effectiveness category than previous research. In previous research, the effectiveness category was in the medium category, whereas in this research, the effectiveness category was in the very high category.

The final step is to analyze students' responses to the treatment. Students' responses to the learning process are in the outstanding category. The response questionnaire includes relevance and reaction indicators (attention, satisfaction, and self-confidence). The analysis results show that 75% of students respond well to the learning process, and 25% show a good response. The percentage diagram of student responses is in Figure 1.

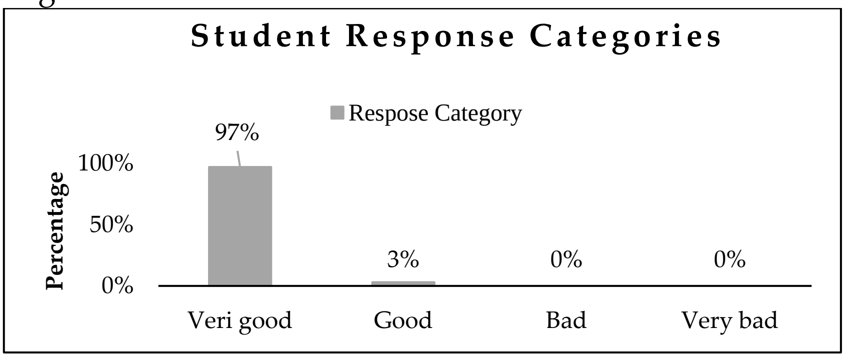

Figure 1. Percentage diagram of student responses

The relevance indicator consists of 6 statements. Statement number 1 received the most answers, with a score of 5: "The learning material taught is by the learning objectives conveyed by the teacher at the beginning of the lesson." A total of 23 students strongly agreed with this statement. This shows that the learning process is carried out by the learning objectives, which can train students' mathematical modeling skills.

The reaction indicator consists of several aspects, namely, aspects of students' attention to the learning process, aspects of students' satisfaction with the learning process, and aspects of students' self-confidence. The aspect of students' attention to the learning process is broken down into 3 statement items, namely numbers 4, 5, and 7. The statement item that gets the most scores of 5 is item 7. Statement number

7 states, " I participated in group discussion activities ."A total of 18 students strongly agreed with this statement. Based on research activities that have been carried out, researchers see that students participate actively during group discussions because they have been assigned tasks. They actively ask researchers questions regarding things they do not understand during problem-solving activities. This proves that researchers have built a comfortable and challenging learning atmosphere. Barret (2017) explained that one of the teacher's roles in the learning process using the PBL model is to encourage a comfortable and challenging learning atmosphere.

The involvement of students in group discussion activities shows that students are motivated to participate in the learning process. Parquet (in Razi & Zhou, 2022) states that one of the goals of the STEAM approach is to motivate students. One factor that can increase students' motivation is using technology (STEAM elements) in the learning process. This is because using technological assistance such as smartphones in the learning process will help students understand the cause of a problem and then relate it to the concept of static electricity. Belbase et al. (2022) also presented the supporting theory that integrating art into learning can motivate students. This is due to the conditions that occur in the field; the researcher saw that the students looked very enthusiastic and discussed among their group members to draw the process of a problem occurring and relate it to the concept of static electricity.

The satisfaction aspect consists of 3 statements, namely statements 6, 8, and 12. The statement that gets the highest score of 5 is statement 6: "I feel happy when I take part in the learning process which aims to find solutions to problems in the environment. around". This statement is statement number 6 in the student response questionnaire. A total of 18 students stated that they strongly agreed that they felt happy when participating in the learning process. Based on the results of the response questionnaire, it can be concluded that students feel happy when participating in the learning process, which aims to find solutions to problems in the surrounding environment. This shows that by implementing the Problem-Based Learning model with a STEAM approach, students can feel happy about participating in the learning process. Researchers saw this during the research; students were very enthusiastic about carrying out experimental activities using Phet Simulation and watching the learning videos that had been prepared. This finding aligns with Parket's opinion (in Razi & Zhou, 2022), which states that the STEAM approach aims to motivate students, increase students' interest in learning, and create meaningful learning that connects everyday experiences to students' learning.

The final aspect of the reaction indicator is the aspect of student self-confidence. The aspects are broken down into three statements, namely 9, 10, and 15. The statement that gets the most scores of 5 is statement number 15. This statement states, "Through the learning process, I am better trained to carry out problem-solving activities ."Seventeen students strongly agreed that they became better trained in problem-solving activities. Students are trained to carry out problem-solving activities. In the opinion of Sakinah et al. (2020), in problem-based learning, students are focused on the problem so that they have the opportunity to understand the problem better. Finally, with a good understanding, students can model problems in mathematical form so that through the PBL model, they can improve students' mathematical modeling abilities. Then, according to Perignat & Katz-buonincontro (2018), students can focus on problem-solving activities through the STEAM approaches through the STEAM approach. So, the STEAM approach can train students' mathematical modeling skills and influence students' learning processes, technical skills, mathematical competencies, and creative thinking abilities (Viet Cuong et al., 2020).

CONCLUSION

The Problem-Based Learning (PBL) model with the STEAM approach is efficacious in improving students' mathematical modeling skills in static electricity material at SMP Negeri 2 Pontianak with a level of effectiveness in the very high category, with student responses in the outstanding category. The recommendations from this research are as follows: (1) The problem used as a starting point must be truly understood by students, making it easier for students to carry out problem-solving activities. (2) The problems raised must come from real life close to students. (3) To make it easier to convey problems, teachers can use media in the form of learning videos to provide a clear picture of the problems for which students will find solutions. Moreover, (4) to follow up on this research, research is needed to develop students' MMA questions on physics material.

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