INDONESIAN JOURNAL OF SCIENCE AND MATHEMATICS EDUCATION
06 (3) (2023) 330-340
https://ejournal.radenintan.ac.id/index.php/IJSME/index
ISSN: 2615-8639
DOI: 10.24042/ijsme.v5i1.18289
November 2023

EXPLORATION OF STUDENTS' SKILLS IN DESCRIBING PHYSICS PROBLEMS: THE EFFECT OF STEM-PROJECT-BASED LEARNING

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Article Info

Article history:

Received: August 3, 2023
Accepted: November 28, 2023
Published: November 30, 2023

Keywords:

Problem-solving
Project-based learning
STEM
Useful description

ABSTRACT

The difficulty students face in describing problems from posed physics-related questions is an indicator that is rarely studied. This research explores students' abilities in describing electrical circuit problems based on implementing STEM-Project Based Learning (STEM-PBL). This study employed a mixed-methods approach with an explanatory model. The subjects were 35 undergraduate Physics Education students at the University of Jambi enrolled in the Electromagnetism course. Data collection was carried out through tests and interviews. The test instrument used five reasoned multiple-choice questions, while the interview instrument used open-ended questions based on the problems identified from the test results. The study's findings revealed an effect size of 2.1 (medium category) and an N-Gain of 0.5 (medium category). Thus, STEM-PBL influences students' ability to describe problems. Future research should investigate the influence of other variables, such as educational background and learning motivation, on the effectiveness of STEM-PBL in developing students' problem-description skills further.

EKSPLORASI KEMAMPUAN MAHASISWA DALAM MENDESKRIPSIKAN MASALAH FISIKA: EFEK DARI STEM-*PROJECT BASED LEARNING*

Kata Kunci:

Pemecahan masalah
Pembelajaran berbasis proyek
STEM
Penggunaan deskripsi

ABSTRAK

Permasalahan mahasiswa dalam mendeskripsikan masalah dari pertanyaan yang diajukan terkait konsep fisika merupakan salah satu indikator yang jarang dikaji. Tujuan penelitian ini adalah mengeksplorasi kemampuan mahasiswa dalam mendeskripsikan masalah rangkaian listrik berdasarkan implementasi *STEM-Project Based Learning* (STEM-PBL). Penelitian ini menggunakan metode campuran dengan model eksplanatori. Subjek penelitian adalah 35 mahasiswa S1 Pendidikan Fisika Universitas Jambi kelas mata kuliah Elektromagnetika. Pengumpulan data dilakukan dengan tes dan wawancara. Instrumen tes menggunakan 5 soal pilihan ganda beralasan, sedangkan instrumen wawancara menggunakan *open ended question* yang disusun berdasarkan permasalahan yang ditemukan dari hasil tes. Hasil penelitian diperoleh nilai *effect size*, yaitu 2,1 (kategori sedang) dan N-Gain 0,5 (kategori sedang). Dengan demikian, STEM-PBL memberikan pengaruh terhadap kemampuan mahasiswa dalam mendeskripsikan masalah. Untuk penelitian selanjutnya, disarankan menginvestigasi lebih dalam pengaruh variabel lain, seperti latar belakang pendidikan dan motivasi belajar, terhadap efektivitas STEM-PBL dalam mengembangkan keterampilan deskripsi masalah siswa.

1. INTRODUCTION

The learning objectives of physics in higher education are to comprehend physics concepts and be able to apply them in problem-solving [1]–[6]. Problem-solving skills are employed by physics instructors as an indicator to assess the concepts learned and are an integral part of the physics teaching mechanism [1], [7], [8]. Students' success in solving given physics problems becomes a benchmark for the effectiveness of the learning process [9].

There are five indicators that students must master to succeed in solving physics problems, namely useful description, physics approach, specific application of physics, mathematical procedure, and logical progression [8], [10]. Among these five indicators, the use of description, also commonly referred to as useful description, is one of the essential abilities students must possess to find solutions to physics problems. Describing involves analyzing information from the problem and employing various representations that summarize essential information in symbolic, visual, and written forms [8]. Describing a problem can include stating known and unknown information, using appropriate symbols for quantities, stating the goal or target to be achieved, sketching or drawing the problem situation such as diagrams, plotting a graph, defining coordinate axes, and/or selecting a coordinate system [11].

Physics instructors in several previous studies often assumed that the difficulties students would experience in problem-solving were related to mathematical skills [12], [13] and the application of concepts [5], [14]. However, not all evidence indicates that this is the main issue. Another problem is using descriptions, which is the student's ability to analyze useful information from the given problems using various representations. This is an essential aspect that also encounters many issues. The ability to describe problems is crucial for students because the process of describing problems in physics problem-solving is the initial stage that will influence subsequent stages in finding solutions to problems. Errors in describing problems can lead to mistakes and difficulties in finding solutions.

The literature review results in this research found many factors that contribute to students' failure in describing problems; among them is the lack of understanding of concepts. This is evidenced by the fact that students can solve simple quantitative problems [15]–[17], but they encounter difficulties when dealing with more complex problems [7]. Many students initiate the problem-solving process by merely writing equations that match the given values in the problem statement [18], [19] or manipulating equations [20]. When solving problems, students often focus on variables or quantitative values in the question rather than the problem being asked [12].

To address these issues, instructors must be innovative in preparing and implementing learning activities [21]–[23]. Several previous studies have attempted to find solutions to enhance students' problem-solving abilities in physics. However, none have specifically focused on improving students' skills in describing problems. Therefore, it is necessary to design learning that can develop students' abilities in describing problems based on appropriate learning theories.

In designing instructional methods, researchers in physics education problem-solving studies often fail to define or utilize theoretical frameworks when creating interventions to develop problem-solving skills [4]. Yet, several theories serve as a foundation for designing interventions to enhance students' ability to describe problems in problem-solving processes, such as information-processing models, problem-solving by analogy, resources model, and situated cognition [4], [7]. These four problem-solving theories can be integrated into the Science, Technology, Engineering, and Mathematics (STEM) approach within the Project-Based Learning (PBL) model.

The selection of STEM-PBL as the instructional approach has clear reasons. Feasibility studies have shown that student involvement in Project-Based Learning offers many benefits, such as experiencing deeper and more meaningful engagement [24], [25] and fostering creative thinking [26]. PBL is a student-centred instructional form based on three principles of constructivist theory: learning is context-specific, students are actively engaged in the learning process, and they achieve their goals through social interaction and sharing knowledge and understanding [27].

STEM, in this case, is due to STEM Education being an example of an environmental catalyst [28], [29]. STEM aims to enable students to acquire problem-solving skills in various disciplines, namely science, technology, engineering, and mathematics [30]–[32]. In this environment, instructors play a crucial role; therefore, individuals and the environment collaborate to develop problem-solving skills through STEM talent [33].

To understand the significance of this research, the researcher conducted a literature review with the assistance of a postviewer to identify novel gaps. The literature review using Postviewer was conducted on 501 articles published from 2018 to 2023. The topics covered in the literature review with the postviewer included STEM, Project Learning, and the ability to describe problems in problem-solving (Figure 1).

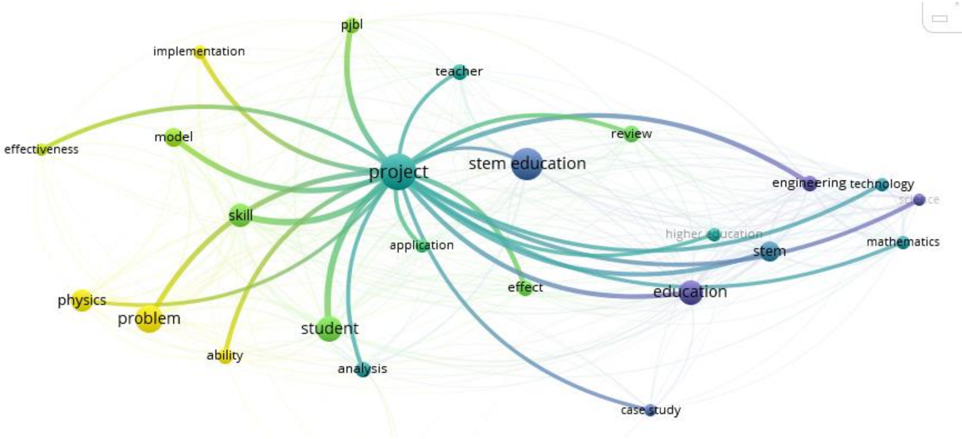

Figure 1. Novelty Analysis Results

The specific analysis results related to project-based learning research, as shown in Figure 1, indicate that this topic has been associated with STEM education. However, no research has been found that connects it with students' ability to describe problems in problem-solving. Based on the abovementioned problems and solutions, this research explores students' ability to describe electrical circuit problems by implementing STEM-PBL.

In addition, research related to exploring student capabilities has been conducted, including students' abilities in solving mathematical problems [34] and cultural context geometry [35], students' critical thinking abilities in calculus problem-solving [36], students' mathematical thinking abilities in solving geometry problems [37], and students' mathematical communication skills [38], However, there has been no research exploring students' abilities to describe physics problems as conducted in this study. This research explores students' abilities to describe physics problems based on learning with STEM-

PBL. Previous research has extensively explored similar capabilities but in mathematical and geometric skills, whereas this research focuses on the ability to describe physics problems. In various physics problems, accurately describing the problem is essential for solving the given tasks.

2. METHOD

This research used a mixed method with an explanatory model. The research design is shown in Figure 2.

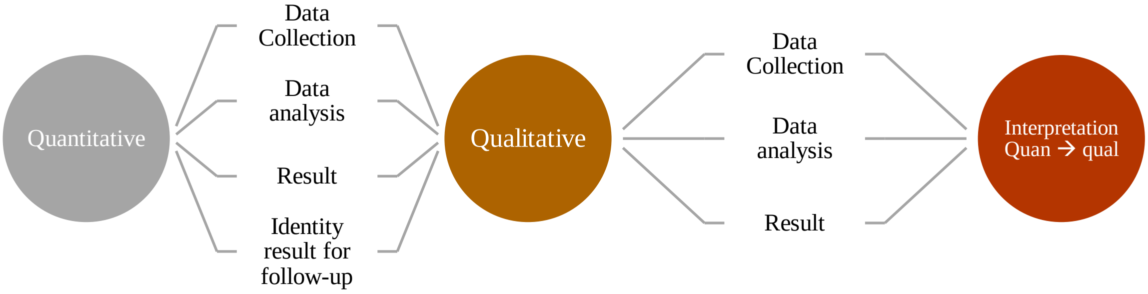

Figure 2. Explanatory Design [39]

Participants in this research were undergraduate students in Physics Education at Jambi University, taking the Electromagnetics course. The participants were 35 students, consisting of 7 males and 28 females. Additionally, several student samples were selected for interviews. The interviews were conducted with students based on the analysis of problem descriptions presented in their test responses.

The instrument used was five reasoned multiple-choice questions adopted from the items developed [40]. Based on the Biserial Correlation KR-20 and Cronbach's Alpha tests, this instrument showed a validity value of 0.65 and a reliability of 0.74 [40]. Meanwhile, the interview instrument was developed based on the findings from the students' test answer sheets.

The research begins with a pretest, aiming to assess the initial ability of students to describe problems from the given questions. The second stage was the implementation of STEM project-based learning. The syntax of STEM-PBL consists of (1) Project team introduction and planning, (2) Initial research phase for information gathering, (3) Creation, development, initial evaluation, and prototype, (4) Second research phase, (5) Final development phase, and (6) Publication of the product or artefact [41]. The third stage was a posttest and interview to determine students' skills in describing physics problems based on the implementation of STEM-PBL.

Table 1. Assessment Rubric for Students' Skills in Describing Physics Problems [8]

5	4	3	2	1	0
Useful description, and presented accurately and comprehensively	Useful description, but some small parts are missing or incorrect	Some parts of the description are not useful, omitted, and contain errors	Most of the description is not useful, omitted, and contains errors	The entire description is not useful and/or contains errors	The solution does not contain a description, and it is necessary to solve this problem

The student test results were analyzed using the rubric in Table 1, while the interview data was analyzed through data reduction. After both data sets were analyzed, data interpretation was conducted. Subsequently, the interpreted results were subjected to an effect size test to measure the magnitude of the impact or influence of STEM-PBL on students' skills in describing physics problems. Furthermore, an N-Gain test was conducted to assess the improvement of students' abilities in describing physics problems.

3. RESULTS AND DISCUSSION

The objective related to problem description skills is not easily achieved because traditional learning has played a prevailing role where the instructor is the "knowledge giver," while the students act as "information receivers" [42]. To change this situation, providing opportunities for students to engage in real problem-solving and knowledge construction within authentic professional contexts, such as STEM-PBL, is appropriate. The results of the data analysis of students' skills in describing physics problems are shown in Table 2.

Table 2. Descriptive Statistics of the Analysis of Students' Skills in Describing Physics Problems

Statistic	Pretest	Posttest
N	35	35
Minimum	0	8,8
Maksimum	12,8	93,6
Mean	5,5	48,3
Effect size	2,1	
N-Gain	0,5	

The results in Table 2 indicate that STEM-PBL greatly impacts students' skills in describing problems. This is evident from Cohen's d-effect size value, which is 2.1 (medium category), and the N-Gain value of 0.5 (medium category). The impact of students' abilities categorized as moderate in describing problems based on project learning experiences may be influenced by projects that are less challenging and ineffective mentoring processes. This aligns with several previous studies, which state that less relevant or challenging projects may not provide optimal opportunities to develop problem-description skills [38]. Additionally, in STEM-PBL, the role of the lecturer is crucial. If the lecturer does not provide sufficient guidance or constructive feedback, learners may struggle to effectively develop problem description skills [39], [40].

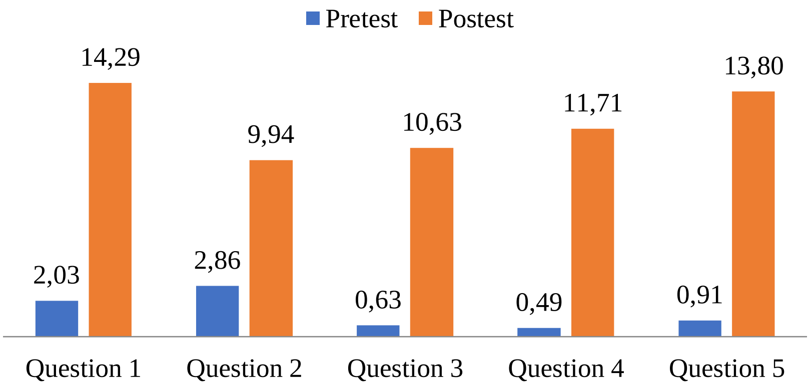

Figure 3. The Average Scores of Students' Pretest and Posttest for Each Item

Based on the results of the calculation of effect size and N-Gain values, both fall under the medium category. Hence, it is necessary to further examine which issues most students experienced in the posttest. To understand the improvement of students' abilities in describing physics problems, the average scores of students' pretest and posttest for each item are presented in Figure 3. Figure 3 illustrates the shift in the distribution of students' skills in describing physics problems from pretest to posttest. Based on Figure 2, it is evident that students' average scores increased for all test items. Several things may contribute to improving students' ability to describe problems; project-based learning encourages the development of critical skills such as analysis, evaluation, and synthesis of information [43], [44]. Students not only receive information, but they also have to process and apply it to generate meaningful solutions [44]. In addition, project-based learning provides a practical context for applying theoretical concepts [45]. Students learn theory and see how these theories can be applied to find solutions.

The smallest shift is observed in students' ability to describe the problem in test item 2. Meanwhile, the largest shift is seen in test items number 1 and number 5. The differences in improvement observed in several test items were also influenced by students' understanding of the related material concepts. If students understand the concepts well, it will affect how they present problem descriptions.

Based on students' responses, several descriptions were found that students used to solve electrical circuit problems. For example, in Figure 4, students were asked to find the solution to test item number 2 related to the potential difference in a circuit. In this case, students described the problem in the question by drawing the circuit to illustrate the conditions of the problem. Then, they qualitatively analyzed the circuit to describe the situation when the switch is open. The circuit becomes a series. In contrast, the circuit combines series and parallel when the switch is closed.

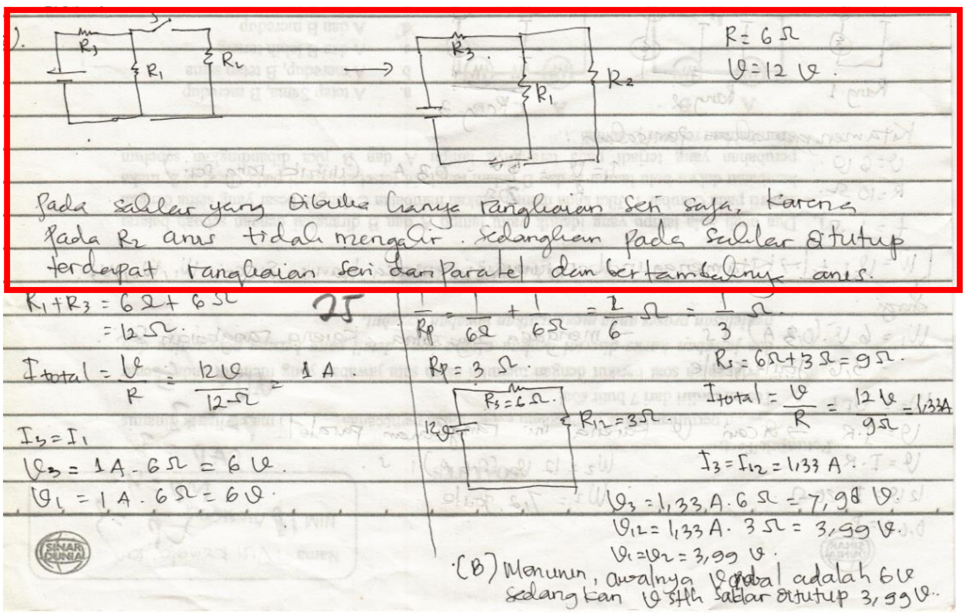

Figure 4. Example of Students' Description

In the problem-solving steps in Figure 4, the descriptions are clear and useful for finding the solution. Several previous studies have explained that problem descriptions presented, as shown in Figure 3, indicate that students are using a scientific approach. Students who apply a scientific approach always begin the problem-solving process by qualitatively analyzing the problem, planning the solution systematically, applying concepts, and evaluating the results of their answers [8], [17]. This type of student has been identified as an expert in problem-solving skills. This is because the expert problem-solving type begins by describing the problem information qualitatively [46] and using the information to identify solution strategies before writing the answer [4], [17], [47], [48].

Another finding in Figure 5 shows a different type of description presented by students to solve the same problem. Students describe the problem by determining the known variables, such as resistance and source voltage, as the initial stage of solution planning. The description in Figure 5 is an example of the most commonly applied problem description by students in finding solutions. Physics novices typically use problem descriptions like this because novices tend to focus on quantitative values in the problem [49], such as variables that are known or unknown in the problem [16], [48].

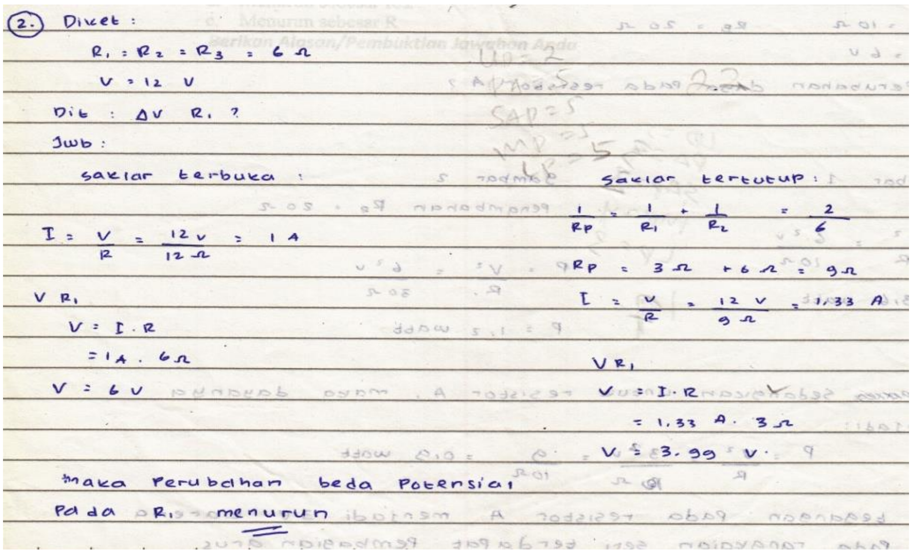

Figure 5. Example of Students' Description

Describing the problem, as shown in Figure 4, is not wrong; however, often, the information presented is irrelevant to finding the problem solution. This is consistent with the results of several studies stating that students who describe the problem based solely on the variables mentioned in the question are more likely to encounter difficulties in finding the answer solution [40], [47].

The ability to describe problems in physics is crucial. This skill is required to organize information from the problem statement and use representations summarising essential information in symbolic, visual, and written forms [8]. Students who can describe problems appropriately will facilitate finding answers to physics problems. This research indicates that STEM project-based learning will be more effective in enhancing students' abilities to describe problems by incorporating scaffolding into STEM-PBL. If the lecturer does not provide sufficient guidance or constructive feedback, learners may struggle to effectively develop problem description skills [50], [51]. Future research should investigate the influence of other variables, such as educational background and learning motivation, on the effectiveness of STEM-PBL in developing students' problem-description skills further.

4. CONCLUSION

Based on the research results and discussion, it is concluded that STEM-PBL has a medium impact on students' skills in describing problems. This is evident from Cohen's d-effect size value, which is 2.1 (medium category), and the N-Gain value of 0.5 (medium category). This study only focused on assessing students' skills in describing problems, and further research is needed to explore other factors that influence students' problem-solving abilities, such as their skills to apply concepts and mathematical skills.

ACKNOWLEDGEMENT

We would like to express our gratitude to the research and community service institution of Jambi University for providing financial support to complete this research. Additionally, thanks to the Physics Education Department of Jambi University for supporting and facilitating this research.

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