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The Effect of Problem-Based Learning E-Module on Students' Problem-Solving Skills in Heat and Heat Transfer Topics at SMAN 2 Koto XI Tarusan

Azzah Afifah[1*], Rio Anshari[1], Desnita[1] , Selma Riyasni[1]

[1]*Department of Physics, Universitas Negeri Padang, Jl. Prof. Dr. Hamka Air Tawar Padang 25131, Indonesia*
Corresponding author. Email:azzahafifah129@gmail.com

ABSTRACT

This research intends to examine how Problem-Based Learning (PBL)-based e-modules influence students' problem-solving skills regarding heat and heat transfer concepts. The study was driven by the inadequate problem-solving abilities noted in students at SMAN 2 Koto XI Tarusan, mainly because of the prevalence of expository teaching techniques and the constraints of traditional learning resources. A quantitative method utilizing a quasi-experimental non-equivalent control group design was utilized. The sample comprised 60 Grade XI students split into two groups: one group utilized PBL-based e-modules, whereas the other group employed traditional materials. Data were gathered through pretests and posttests consisting of essay questions. The Mann-Whitney U test was utilized because the data did not follow a normal distribution. Findings showed a notable difference in problem-solving skills between the two groups. The experimental group demonstrated a significant rise in the average score of the posttest (77.10) in contrast to the pretest (40.03), whereas the control group saw a slight increase from 44.00 to 58.07. Enhancements were noted in all problem-solving metrics. Analysis of data using the Mann-Whitney test indicated a statistically significant difference in problem-solving abilities between the experimental group and the control group. The findings from the Mann-Whitney test showed a significance level of <0.05, thereby underscoring a significant impact of the use of project-based learning (PBL) e-modules on improving students' problem-solving skills specifically concerning heat and thermal transfer. This methodological framework has demonstrated success in tackling current challenges, aligning with the requirements of 21st-century skills and the implementation of the Independent Curriculum.

Keywords: E-Module; Problem Based Learning; Problem Solving Skills; Heat and Heat Transfer

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I. INTRODUCTION

Education serves as the fundamental basis for cultivating individuals who possess extensive knowledge, robust character, and the ability to adapt to the ever-changing landscape of contemporary life. In the 21st century, the expectations for high-quality education are on the rise, with students required to develop a set of crucial skills referred to as the 4Cs: critical thinking, creativity, problem-solving, communication and collaboration, and digital literacy [1]. Among these competencies, problem-solving skills are particularly significant, as they empower individuals to analyze, assess, and systematically address complex issues [2][3]. This skill set is not only applicable in daily life but is also essential in the realm of science education, especially in physics.

In the realm of physics education, which explores natural phenomena and essential concepts like heat and heat transfer, problem-solving skills are vital for students to effectively apply scientific principles in practical situations [4]. However, real-world observations reveal considerable challenges. Initial assessments at SMAN 2 Koto XI Tarusan showed that students exhibited low problem-solving abilities in physics, especially regarding heat and heat transfer, which they also found challenging [5][6]. This was evident in pretest results that fell significantly short of the Minimum Completion Criteria (KKM), alongside students' struggles with grasping concepts, formulating mathematical equations, and a general lack of problem-solving skills. This situation is further aggravated by the prevalence of passive expository teaching methods and a limited range of conventional

instructional materials, which contribute to a monotonous and less engaging learning experience, thereby hindering the development of the 21st-century skills highlighted in the Independent Curriculum [7].

To address these challenges, this study aims to find solutions by implementing innovative learning models that are enhanced by modern teaching materials. The Problem-Based Learning (PBL) model has been selected as the primary approach due to its student-centered nature and its effectiveness in fostering critical thinking, creativity, and problem-solving skills through the exploration of real-world issues [8][9]. PBL promotes active student engagement in identifying problems, gathering data, conducting investigations, and formulating solutions [10], thereby facilitating the development of higher-order thinking skills [11]. To ensure effective implementation of PBL, this study incorporates the use of e-modules. E-modules are structured, interactive digital teaching resources that include multimedia components such as text, images, videos, and animations [12][13]. The benefits of e-modules include their ability to present content in an engaging way, support a variety of learning activities, and provide flexible access, aligning with their self-instructional and user-friendly features [14].

The use of this approach is consistent with the objectives of the Independent Curriculum, which prioritizes the formation of the Pancasila Student Profile and empowers educators to adapt learning resources based on students' characteristics and interests [15][16]. Within this curriculum, physics education is directed toward fostering students' understanding of natural phenomena and core scientific concepts through contextual, flexible, and student-centered learning strategies [17].

Several pertinent studies have highlighted the positive impact of combining PBL with digital learning materials. Armanda & Putra [18] and Juanda & Festiyed [19] observed a significant influence of PBL-based e-worksheets or e-modules on students' competency levels and creative thinking abilities. While their research had different focal points, Putri et al. [20] also validated the effectiveness of the PBL model in enhancing learning outcomes. In particular, Herawati & Wilujeng [21] noted improvements in problem-solving skills through the use of PBL e-modules. As a novel contribution, this study employed e-modules reviewed by Aulia et al. [22] that are accessible online via the Heyzine-Flipbook software, a feature that has not been extensively explored in the context of physics education.

Drawing from the discussion above, this research aims to evaluate the influence of implementing PBL-based e-modules in the subject of heat and heat transfer on the problem-solving abilities of students at SMAN 2 Koto XI Tarusan. The findings of this study are expected to contribute meaningful empirical support for the use of PBL-based e-modules as an effective approach to enhance students' problem-solving skills in physics. Moreover, it seeks to strengthen the implementation of the Independent Curriculum and promote the integration of digital technology in the learning process.

II. METHOD

The study carried out is a quantitative analysis employing a quasi-experimental approach. The design used is a nonequivalent control group design, comprising two groups: an experimental group and a control group that are not randomly chosen [23]. In this research, the investigator will provide a PBL-focused e-module to the experimental group, whereas the control group will undergo no intervention. Before the treatment, both groups will undergo a pretest to evaluate their initial problem-solving skills. After the treatment, both groups will participate in a posttest to assess the effect of the intervention.

Table 1. Research Design

Class	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_2
Control	O_1	X_1	O_2

Description :

O_1 : Pretest in experimental and control classes
O_2 : Posttest in experiment and control classes
X_1 : Physics learning treatment through PBL-based e-modules
X_2 : Physics learning treatment through the application of PBL

This study involved four Grade XI Phase F classes from the science specialization track at SMAN 2 Koto XI Tarusan as research participants.

The experimental and control classes were selected using a nonprobability sampling technique, specifically purposive sampling. The sample was chosen based on several predetermined criteria, including the number of

students and their final exam scores for the odd semester of the 2024/2025 academic year. Statistical tests were then applied to designate Grade XI Phase F3 as the experimental class and Grade XI Phase F1 as the control class. Both classes had identical average final exam scores of 88.

This study identified the PBL-integrated e-module on heat and heat transfer as the independent variable, and students' problem-solving skills at SMAN 2 Koto XI Tarusan as the dependent variable. Data collection was conducted quantitatively through the use of a testing instrument.

The research instrument employed in this study was a test designed to assess problem-solving abilities, consisting of essay questions. This test has been validated by prior researchers and has a reliability coefficient of 0.60, with an XY correlation value of 0.43. The instrument includes physics problems related to heat and heat transfer presented as case studies, which will be administered as pretests and posttests to both the experimental and control classes.

This study employed pretest and posttest data collection methods to assess the effects of the treatment on both the experimental and control classes before and after its implementation. The data analysis process involved the application of normality, homogeneity, and hypothesis testing techniques.

III. RESULTS AND DISCUSSION

Result

This research was carried out by the researchers from April 24, 2025, to May 24, 2025, at SMAN 2 Koto XI Tarusan. The study involved two classes as sample groups: class XI Phase F3 served as the experimental class, which received treatment through the use of PBL-based e-modules, while class XI Phase F1 acted as the control class and did not receive any treatment. The research was conducted over approximately one month, with each week consisting of two meetings in each class, each lasting 1 × 40 minutes. The study generated data in the form of pretest and posttest scores for both classes. The following section outlines the implementation of learning using PBL-based e-modules throughout the learning process.

1. Problem Solving Ability Pretest Results

Table 2. Problem Solving Ability Pretest Results

Centralization and Dissemination of Data	Experimental Class	Control Class
Total Students	30	30
Maximum Score	56	56
Minimum Score	20	33
Mean	40,03	44
Median	37	45
Standard Deviation	7,393	6,491

The table above presents the main characteristics and spread of pretest scores for the experimental and control groups. All groups attained a maximum score of 56. However, their lowest scores varied: the experimental group's minimum was 20, whereas the control group's lowest was 33. Furthermore, the control group achieved a higher average score of 44, while the experimental group had a mean score of 40.03. The figures indicate that the median score for the experimental group was 37, compared to 45 for the control group.

2. Students' Initial Problem Solving Ability for Each Indicator

Table 3. Percentage of Students' Initial Problem-Solving Ability Indicators

Indicator	Maximum Score	Pretest			
		Experimental Class		Control Class	
		Xbar	%	Xbar	%
Identify the problem	20	14,83	74,17	15,07	75,33
Formulate a solution strategy	30	16,67	55,56	17,8	59,33
Execute the solution	20	7,27	36,33	8,23	41,16
Review and verify the outcome	30	1,23	4,11	2,9	9,66
Total Score	100	40		44	

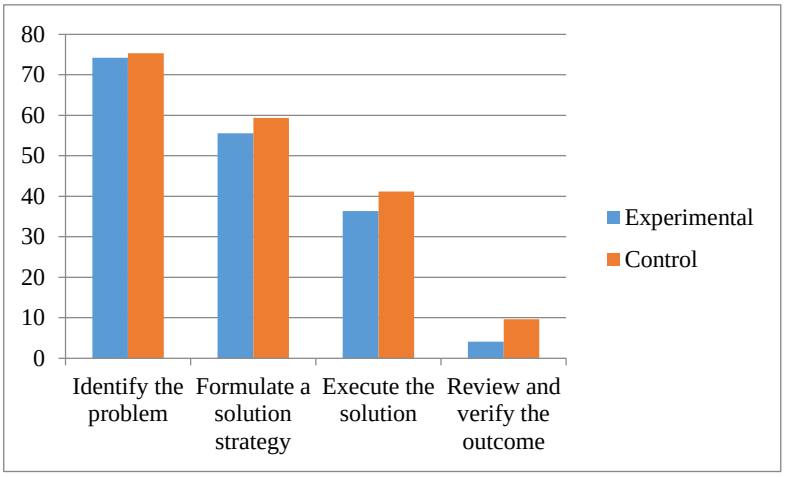

Fig. 1. Percentage Graph of Pretest Scores

In general, the total average score in the control class surpassed that of the experimental class. The figure and table above further illustrate that the initial abilities of students in both classes were fairly comparable, with the control class exhibiting a slight advantage across all indicators.

3. Problem Solving Ability Posttest Results

Table 4. Problem Solving Ability Posttest Results

Centralization and Dissemination of Data	Experimental Class	Control Class
Total Students	30	30
Maximum Score	95	85
Minimum Score	45	20
Mean	77,10	58,07
Median	79	59,50
Standard Deviation	12,813	10,998

The table above shows the central tendency and distribution of posttest results for both the experimental and control groups. In the experimental class, the maximum score reached was 95, while the maximum score in the control class was 85. The minimum score noted in the experimental class was 45, whereas the control class recorded a lowest score of 20. The experimental class had an average score that exceeded the control class, achieving 77.10 while the control class averaged 59.50. Furthermore, the table shows that the median score for the experimental group was 79.50, whereas the median for the control group was 59.50.

4. Students' Final Problem Solving Ability for Each Indicator

Table 5. Percentage of Students' Final Problem-Solving Ability Indicators

Indicator	Maximum Score	Posttest			
		Experimental Class		Control Class	
		Xbar	%	Xbar	%
Understand the problem	20	18,50	92,5	16,07	80,33
Plan problem solving	30	27,10	90,33	22,47	74,89
Solve the problem	20	17,53	87,67	13,4	67
Check the results of problem solving	30	13,97	46,56	6,13	20,33
Amount	100	77,10		58,07	

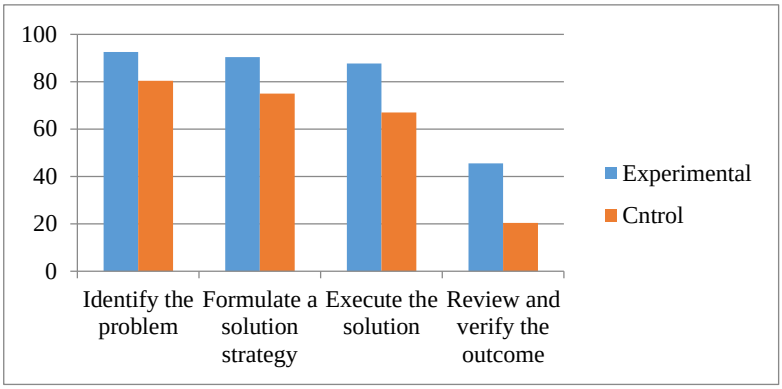

Fig. 2. Percentage Graph of Posttest Scores

To sum up, the average score in the experimental group exceeded that of the control group. The figure and table above also show that the students' final abilities in both classes enhanced when assessed against their initial skills. This suggests that employing PBL-oriented e-modules positively influences the problem-solving skills of students in the experimental group.

5. Test Statictical Analysis Prerequisites

a. Normality Test

The normality test is conducted to assess whether the data population follows a normal distribution. This assessment is crucial for identifying the appropriate statistical test that will be applied to evaluate the acceptance or rejection of the hypothesis. Data is categorized as normally distributed or not according to the results of the normality test, where if sig. $\alpha > 0.05$, the data is regarded as normally distributed, and if sig. $\alpha < 0.05$, the data is considered not normally distributed.

Table 6. Normality Test Results

Saphiro - Wilk	Pretest		Posttest	
	Experimental	Control	Experimental	Control
Statistic	0,941	0,928	0,928	0,640
df	30	30	30	30
Sig	0,097	0,045	0,042	0,000
Description	Normal	Abnormal	Abnormal	Abnormal

The table above indicates that the significance values (α) for the control group's pretest and posttest are below 0.05, implying that the data do not follow a normal distribution. On the other hand, the pretest in the experimental group reveals a significance value exceeding 0.05, suggesting that the data adhere to a normal distribution. Conversely, the control group's posttest again shows a significance value below 0.05, confirming that the data distribution is non-normal.

b. Homogenity Test

A homogeneity test was conducted to assess whether the variance of data in both classes was similar (homogeneous) or not. This examination employed the Levene Statistic, establishing a significance threshold (α) at 0.05. The standards for evaluating homogeneity were these: when the significance value (α) is greater than 0.05, the data variances are considered equal or homogeneous; when the value is less than 0.05, the data variances are viewed as unequal or non-homogeneous.

Table 7. Homogenity Test Results

Levene Statistic	Pretest		Posttest
Sig	0,478		0,038
α		0,05	
Description	Homogeneous		Non-Homogeneous

Based on the table above, the significance value for the pretest is greater than 0.05, indicating that the data is homogeneous. On the other hand, the posttest results show a significance value lower than 0.05, signaling an absence of homogeneity in the data.

c. Hypothesis Test

Hypothesis testing serves to assess whether an initial assumption can be accepted or must be rejected. Since the prerequisite tests indicated that both the pretest and posttest data in the experimental and control groups were not normally distributed, the Mann-Whitney U test was applied to analyze the pretest and posttest results.

Table 8. Hypothesis Test Results

	U Test		
	Sig	**α**	**Description**
Pretest F3 and Posttest F3	0,00	0,05	H_1 is accepted
Pretest F1 and Posttest F1	0,00		H_1 is accepted
Pretest F3 and Pretest F1	0,04		H_1 is accepted
Posttest F3 and Posttest F1	0,00		H_1 is accepted

The table demonstrates that all four tests produced significance (Sig) values less than 0.00, which is below the 0.05 limit. This finding endorses H1, indicating that PBL-based e-modules on heat and heat transfer notably influence students' problem-solving skills.

Discussion

This research aims to examine the effects of Problem Based Learning (PBL) e-modules on heat and heat transfer topics related to the problem-solving abilities of students at SMAN 2 Koto XI Tarusan. The results indicate a notable impact of using PBL-focused e-modules in improving the problem-solving skills of students in the experimental group in contrast to the control group. This result directly tackles the concerns identified in the research background, especially the insufficient problem-solving abilities of students in physics learning, notably regarding heat and heat transfer subjects, along with the limitations of conventional teaching approaches and resources.

The background section reveals that initial results at SMAN 2 Koto XI Tarusan demonstrated students' inadequate problem-solving abilities in physics, illustrated by pretest scores that significantly fell below the Minimum Completion Criteria (KKM). The findings from the pretest in this study backed this scenario, showing that the average pretest scores for the experimental group (40.03) and the control group (44) were both quite low, indicating that the students' initial problem-solving abilities in both groups were quite similar. This issue was worsened by students' struggles in grasping concepts, formulating mathematical equations, and their deficiency in solving physics problems, particularly related to heat and heat transfer, which were considered difficult [5][6].

Another issue emphasized in the background is the dominance of passive expository learning approaches and the restricted variety of traditional instructional resources. This method of learning often reduces the involvement in the educational experience and hinders the growth of 21st-century skills, such as problem-solving abilities [7]. To address this challenge, the research utilized a PBL framework in conjunction with e-modules. The posttest findings clearly demonstrated the method's effectiveness, with the experimental group's average posttest score significantly increasing to 77.10, far exceeding the control group's average score of merely 58.07. This improvement was also evident in all measures of problem-solving skills, with the experimental group's percentage score significantly surpassing that of the control group after the intervention.

The significant improvement observed can be linked to the distinctive characteristics of the PBL model and the advantages provided by e-modules. As stated earlier, PBL promotes a student-centered approach that enhances critical thinking, creativity, and problem-solving skills by involving learners in real-world problem situations [8][9]. This research presented a PBL-oriented e-module containing physics tasks focused on heat and heat transfer in important contexts, encouraging students to engage in identifying problems, collecting relevant data, performing investigations, and proposing solutions. This teaching method involves students in all phases of problem-solving—from understanding the issue and developing a plan to implementing the solution and assessing the results—reflecting the essential indicators of problem-solving ability.

The incorporation of e-modules significantly improves the efficiency of the PBL method. Systematic and engaging e-modules that include multimedia components like text, images, videos, and animations [12][13] deliver the content attractively and support different learning tasks. The availability of e-modules via the Heyzine-flipbook software enables students to study autonomously (self-guided) at their individual pace, greatly enhancing exploration and problem-solving activities outside of class time. This method is consistent with the tenets of the Independent Curriculum, highlighting teachers' autonomy to select resources that address student needs and interests while encouraging the investigation of natural events [15][16][17].

The results of this study are consistent with past studies that have also shown the advantages of integrating PBL with online learning materials. According to Armanda & Putra [18] and Juanda & Festiyed [19], PBL-focused e-worksheets or e-modules significantly improved students' ability to acquire new skills and think creatively. Furthermore, Herawati & Wilujeng [21] especially noted that the use of PBL e-modules improved problem-solving skills. This study offers solid empirical evidence, particularly with regard to heat and heat transmission at SMAN 2 Koto XI Tarusan, and emphasizes the benefits of using online e-modules delivered via a flipbook-heyzine as a cutting-edge approach to delivering educational materials.

To sum up, the usage of PBL-centered e-modules has demonstrated to effectively address students' inadequate problem-solving skills in physics education. In addition to improving student performance, this approach radically alters how students engage with challenges and information, which is consistent with the objectives of 21st-century education and the Independent Curriculum's implementation.

IV. CONCLUSION

According to the findings and discussions, it can be concluded that students in grade XI Phase F1 and XI Phase F3 exhibit markedly different problem-solving abilities concerning heat and heat transfer when utilizing PBL-based e-modules rather than the traditional teaching resources commonly used in schools. The students' posttest findings, indicating a significance level of Sig <0.001 (Sig <0.05), validate this, thus H1 is accepted. This suggests that the use of PBL-based e-modules significantly affects students' problem-solving abilities at SMAN 2 Koto XI Tarusan.

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