The Effect of STEM Approach with Assessment Formative in PBL on the Problem-Solving Ability of Prospective Physics Teacher on Mechanical Wave

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Abstract. Mechanical wave matter is abstract material so it is still difficult to understand and affect to students' problem-solving abilities (PSA). PSA is needed to understand and solve physics problems using accurate methods. The solution in an effort to improve the PSA of mechanical wave materials is to apply the STEM approach with Assessment Formative (STEM – AF) in Problem-Based Learning (PBL). This study aims to determine the effect of the application of STEM – AF in PBL on the PSA of prospective physics teachers in wave material. This research uses a mixed method with an experimental embedded design. The research was conducted on Physics education students of Nusa Cendana University, Class of 2022. The research instruments used were mechanical wave problem-solving test questions modified from Mechanical Wave Conceptual by Tongchai et al., (2020) and interview guideline instruments. The results showed that there is an influence of STEM – AF in PBL on the PSA of mechanical wave materials. The effect can be seen from (1) the difference between the PSA of the experimental class and the control class, (2) the N-gain test value of the experimental class is 0.52 higher than the N-gain value of the control class 0.42, and (3) each indicator of the PSA of the experimental class is higher than each indicator of the PSA of the control class. These results are supported by qualitative data where STEM – AF improves students' PSA with product manufacturing process activities and question practice activities with appropriate procedures and accompanied by feedback. For future research, it is recommended to apply STEM – AF in Project Based Learning classes to mechanical wave materials.

Keywords: PBL-STEM-AF, Mechanical Wave, Physics Teaching

1 Introduction

Mechanical material is difficult to understand because it is abstract so it requires prediction and understanding in real life [1]. Studying mechanical wave material can be done by creating a simple practicum tool from technology that uses the concept of me-

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chanical waves with the ultimate goal of understanding phenomena and matter mechanical waves [2]. Technology that uses the concept of mechanical waves as the basis for its use can be a real example for understanding mechanical wave matter[3]–[6].

Previous studies related to mechanical wave matter have shown that mechanical wave matter is still as difficult to understand as the difficulty in understanding submatter related to walking waves, waves stationary, and sound waves[7]–[9]. The difficulty in understanding mechanical wave matter shows that mastery of mechanical wave matter is still lacking. [9], [10] Lack of mastery of the material affects the problem-solving ability of students [11], [12].

Problem-solving abilities (PSA) are developed by solving Physics problems in Basic Physics learning [13]. Several studies have been conducted to overcome the ability to solve physics problems by applying various learning models and strategies, namely blended learning, cooperative strategies and solving collaboration issues, android-based mobile learning applications, and by implementing PBL models [7], [11], [14]–[17]. PBL models are proven to improve PSA, especially in physics materials for mechanical materials, temperature and heat, optics, light, and static fluids. [18]–[22] From some of these studies, it is rare to find its application in students for mechanical wave materials.

PBL learning itself is not enough to follow up in applying the knowledge gained and has not been able to help students solve problems about technology that uses concepts of mechanical waves by generating miniatures of such technology [6], [23], [24].

The shortcomings of PBL can be overcome with a STEM approach because the result of STEM is a product in the form of a technology miniature that can train PSA by applying the knowledge gained [25]. The application of STEM in PBL requires process assessment to recognize and respond to learning activities to develop PSA that can be met by formative assessment [26], [27]. Thus, applying STEM – AF in PBL is important to develop students' PSA on mechanical wave materials.

2 Method

The research method used is a mixed method with an embedded experimental design. The research was conducted on 50 students of Physics education at Nusa Cendana University class of 2022. Participants consisted of 2 classes, namely an experimental class that applies STEM – AF in PBL and a control class that applies PBL only.

The research data were obtained from the results of pre-test and post-test problem-solving abilities (PSA), formative test results at the end of round 1 and round 2, and interview results. Round 1 learning for the experimental class is in the form of practicum activities on rope-wavelength tension relationships and project work with the guidance of STEM worksheets whose final result is a simple musical instrument using a rope. Round 2 learning for experimental classes in the form of practicum activities on intensity levels and project completion with the guidance of STEM worksheets whose final results are frequency reduction tools. Meanwhile, round 1 learning for the control class is in the form of practicum activities on rope-wavelength tension relationships, and round 2 learning for control classes is in the form of practicum activities on intensity levels.

The research instrument used is problem-based written test questions related to mechanical wave material modified from the Mechanical Wave Conceptual Survey by Tongchai et al which is adjusted to the format of PSA. The data collected consisted of quantitative data in the form of pre-test and post-test results of PSA and qualitative data in the form of interviews and observations during learning. The quantitative data collected were analyzed using independent samples t-test, N-gain, and effect size. The qualitative data collected are analyzed using data exposure, data reduction, and inference.

3 Results

Problem-solving ability (PSA) can be identified using an assessment of PSA indicators. The study began with the provision of pre-test and post-test PSA in experimental classes and control classes about mechanical waves. The pre-test data of the PSA of the experimental class and the control class were analyzed to prove that the initial state of the two classes was the same so that they could be given treatment. The results of the pre-test data analysis showed that there was no difference in initial PSA between the experimental class and the control class. This can be seen from the test results of normality, homogeneity, and differentiation. The pre-test data of PSA was declared normal with an experimental class Sig value of 0.373 and a control class Sig value of 0.475. The pre-test data of the PSA of the two classes were also declared homogeneous with a Sig value of 0.742 and were declared not significantly different from the difference power results with a Sig value of 0.461.

After being treated, post-test data on PSA were analyzed to determine the effect of applying the treatment given to both classes. Post-test data of PSA were analyzed by prerequisite tests, independent samples t-test, N-gain test, and effect size. The results of the pre-required analysis of post-test data are shown in the following table

Table1. Precondition Test Results

Test Data Precondition Post-Test PSA	Experimental Class	Control Class	Interpretation
Normality	0,122	0,277	Normal
Homogeneity	0,265		Homogeneous

Table 1 shows post-test data on the PSA of both normal and homogeneous classes so that further analysis can be carried out, namely independent samples t-Test, N-gain test, and effect size. The results of the three tests can be seen in Table 2 below. Table 2 shows that there is a significant difference between the PSA of experimental and control class students with a Sig value of 0.011. The difference in the PSA of the two classes is seen from the experimental class's N-gain score, which is greater than the control class's N-gain score. These results are corroborated by the results of the effect size which shows the difference between the two classes including height with an effect size value of 0.7589.

Table 2. Post-Test Data Analysis Results Problem-Solving Ability

Test Type	Experimental Class	Control Class
Independent Samples t-Test	0.011 (significant difference)	
N-Gain Score	0.52 (Medium)	0.42 (Medium)
Effect Size	0.7589 (Large effect size)	

Based on the results of the analysis also showed an increase in each indicator of experimental class PSA higher than the control class seen in the table of N-gain test results for each of the following PSA indicators

Table 3. N-gain Test Results of Each PSA Indicator

PSA Indicator	N-gain	
	Experiment Class (Category)	Control Class (Category)
Visualization (Problem Description)	0,74 (High)	0.60 (Medium)
Physics Approach	0.51 (Medium)	0.39 (Medium)
Specific Applications of Physics	0.57 (Medium)	0.46 (Medium)
Mathematical Procedure	0.48 (Medium)	0.39 (Medium)
Logical Continuity	0.39 (Medium)	0,32 (Medium)

The results in Table 3 confirm that STEM-AF treatment in PBL has a greater effect than treatment with PBL. This is also supported by the results of the PSA levels of the experimental class and the control class shown in the following table

Table 4. Level of PSA Ability

Level KPM	Experiment	Control
Novice	0	0
Intermediate-lower	0	3
Intermediate-upper	20	21
Expert-like	5	1

Table 4 highlights the previous results, namely that STEM-AF treatment in PBL has more influence on students' PSA in mechanical wave materials. Table 4 shows the experimental class's PSA level higher than the control class's. The influence on the results of the PSA level is strengthened by the effect size result of 0.7589 which shows that there is a high difference between the experimental class and the control class so that it provides opportunities to be applied on a large scale. The quantitative results obtained are corroborated by qualitative data in the form of interviews analyzed with the results in Table 5 below.

Table 5. Interview Analysis Results

Class	Idea	Theme
Experiment	Practicum Project Quiz Video	Activities That Help Understand Concepts
	Able to analyze problems Easy to solve problem-based problems	Effect on Problem-Solving Ability
	More active and conscientious Increase motivation Understand the concept or material	Influence after Learning
Control	Practicum	Activities That Help Understand Concepts
	Able to solve problem-based	Effect on Problem-Solving Ability
	Understand the concept or material	Influence after Learning

Table 5 shows the differences in learning activities that affect students' PSA in experimental and control classes. Learning activities that affect students' PSA in experimental classes are more varied than in control classes.

4 Discussion

The results showed that the PSA of students in the mechanical wave material of the experimental class was higher than that of the control class. These results are supported by Parno et al. (2019), the PSA of students in PBL – STEM – AF classes are better than the problem-solving ability of students in PBL classes. Putri et al. (2018) also showed the same result, namely the application of STEM – AF affects students' for the better. Learning with PBL helps students be interested in solving problems in the form of real-world phenomena so that they can improve PSA [31]. STEM activities in applying theory through the practice of making projects by introducing engineering technology can help students in training and improving the learning experience of solving problems with appropriate procedures. Formative assessment also helps in practicing PSA with formative practice activities accompanied by feedback [22], [32]

PBL learning influences indicators of PSA in STEM – AF in PBL helps influence PSA by solving problems from video presentations, narration, practicum, and projects. Problem-solving is done by seeing the situation as an identifiable problem then the PSA, especially visualization indicators, can be well-trained [33]. Then, choosing solutions in the form of concepts or theories that can train the problem-solving ability of physics approach indicators and determining solutions in the form of equations can train the PSA of physics-specific application indicators [33], [34]. The next activity is to solve problems with proper procedures and correctly train PSA indicators of mathematical procedures. Problem-solving ends with the activity of making conclusions from the problem-solving process, training indicators of logical continuity [12].

These activities can train all indicators of problem-solving ability so that they can develop students' PSA. Learning PBL using STEM – AF can affect students' PSA better than PBL models alone. This can be seen from the results of *the independent samples t-test* with a value of Sig. 0.011 < 0.05 which shows a significant difference between students' PSA on mechanical wave material for experimental classes and control classes. This result is also supported by the N-gain test results which show the effectiveness of STEM application – AF in the PBL class has a medium-level N-gain score with a score of 0.52 and the PBL class has a medium-level N-gain score with a score of 0.42. The difference in effectiveness is convinced by the effect size results, which is in the high category with a value of 0.7589. Both results are sufficient to support the results of *independent samples t-test* which shows the effect of STEM – AF in PBL classes is more influential on students' PSA on mechanical wave materials.

The N-gain test results of each indicator in Table 3 show visualization indicators have the highest N-gain scores and logic continuity indicators have the lowest N-gain scores for both classes. The visualization indicator has the highest N-gain score because in PBL learning students are trained to see each situation as an identifiable problem [33]. The experimental class had a higher N-gain score on visualization indicators than the control class because visualization indicators were continuously trained in performing projects using a blend of STEM and formative test activities. Meanwhile, the logic continuity indicator has the lowest N-gain score because students do not understand the basics of physics related to physics concepts and equations so that the conclusions made are incomplete and unfocused or inconsistent [35], [36]. However, the logic continuity indicator of the experimental class has a higher N-gain score than the control class. This is due to the help of STEM which has procedures in solving problems so as to help students in making better conclusions about the problem-solving process [33]. Formative practice activities accompanied by feedback also train students to reflect and evaluate the problem-solving process well.

The results of the N-gain test are also corroborated by the results of the problem-solving ability levels seen in Table 4. The PSA level of the experimental class is higher with 5 expert-like level students and the control class with 1 expert-like level student. STEM approaches can provide problem-solving learning experiences with product manufacturing [22]. STEM approaches also help introduce engineering technologies that train problem-solving in learning [32]. This is supported by the results of the interview experimental class has more activities in influencing PSA compared to the control class.

5 Conclusion

Data and analysis of the results showed that the application of STEM – AF in PBL had a better effect on students' PSA in mechanical wave materials. These results can be seen from the results of independent samples t-test 0.011; experimental class N-gain test of 0.52 and for control class 0.42. The N-gain test for each indicator of problem-solving ability and PSA level of the experimental class is also higher than that of the control class. This is corroborated by the results of the effect size test which shows the difference in PSA between the two classes is included in the high category. For future research, it is recommended to apply STEM – AF in Project Based Learning classes by focusing more on working on projects to develop PSA.

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