

Implementing the Missouri Mathematics Project Learning Model to Enhance Students' Physics Problem-Solving Skills

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ABSTRACT

Problem-solving is a critical competency for students, particularly in physics education. However, observations and literature reviews indicate that students' physics problem-solving abilities remain low. This deficiency is often linked to underdeveloped mathematical skills, which are essential for understanding and applying physics concepts. This study aims to analyze the significant differences in students' physics problem-solving abilities between those taught using the Missouri Mathematics Project (MMP) model and those taught using conventional instructional methods. This quasi-experimental research employed a nonequivalent control group design. The study was conducted at Madrasah Aliyah Negeri (MAN) Tanjungbalai, which has a population of 95 students. A purposive sampling technique was used to select 47 students, divided into experimental and control groups. The instruments used were a physics problem-solving test consisting of five essay questions and a student response questionnaire. Data were analyzed using the independent t-test. Findings reveal that students in the experimental group, taught using the MMP model, demonstrated significantly higher problem-solving ability than those in the control group. This is evidenced by the N-Gain scores: the experimental class achieved an average N-Gain of 0.74, compared to 0.51 in the control class. The results indicate that the MMP model positively influences students' physics problem-solving skills. The structured and collaborative nature of MMP may enhance conceptual understanding and application, suggesting its potential as an effective teaching strategy in physics education.

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1. INTRODUCTION

The acquisition of data by PISA shows that Indonesia was ranked 2nd bottom in 2012 which had an average score of 382, while the next 3 years, namely in 2015 Indonesia obtained a score of 403 which showed that Indonesia had improved, but in 2018 the score obtained decreased with a score of 396, this

resulted in Indonesia being ranked 71 out of 79 countries (Schleicher, 2019). In 2021 the results of the PISA survey show that the problem solving skills possessed by students in Indonesia are at the bottom of the rankings and even only slightly above the bottom with an average international score of 375 out of 500 (Khairunnisa & Ramlah, 2021), so that the final results in the level of thinking in the form of knowledge, understanding and application in Indonesian education are still relatively low (Syukri et al., 2021)

Field observations at MAN Tanjungbalai indicate that students' physics problem-solving abilities remain relatively low. During classroom observations, students were often disengaged – displaying inattentiveness, lack of focus, and passivity during instructional sessions. Firmansyah et al. (2022) suggest that this deficiency stems from the limited opportunities students have to engage with practice problems, which hampers the development of essential problem-solving skills and contributes to poor academic performance. According to Yulistiana and Setyawan (2020), infrequent problem-solving practice leads students to rely heavily on teacher demonstrations without internalizing problem-solving strategies. Moreover, Nursyifaa and Senjayawati (2018) highlight a lack of instructional innovation as a contributing factor. Observations further revealed that teachers often prioritized completing the curriculum over reinforcing concepts, resulting in minimal use of additional assignments or opportunities for review. Although a few questions were posed during lessons, they largely mirrored example problems, offering little variation. Students also demonstrated fundamental skill deficiencies, such as inaccuracies in mathematical calculations, unit conversions, and formula application. Consequently, students' problem-solving abilities remain below the Minimum Mastery Criteria (KKM) of 78 set by the school.

This low ability is not in accordance with the demands needed that the ability needed in the field of physics is the ability to solve physics problems. This is part of the current educational demands because in physics learning there are many problems related to natural phenomena that must be resolved (Silvianti et al., 2022). Physics learning requires students to be able to think and process in understanding concepts, analyzing problems, find solutions and applying these solutions to solve problems (Syukri et al., 2023). Problem solving is a complex matter because it has an important role in mathematical learning, one of which is in physics learning. One of the main objectives of physics learning is that students must be able to become good problem solvers so that they have the expected capacity for problem solving skills (Nisyah et al., 2019). Problem solving can be interpreted as an attempt to find a way out of a difficulty (Bhenge et al., 2022). Problem solving involves finding ways to achieve a goal based on the characteristics of the problem being solved so that certain steps are needed. It is important for students to strategize in solving problems appropriately, such as solving physics problems well (Isra, 2023). Therefore, problem solving is one of the competencies that must be possessed by students to the fullest.

Referring to these problems, a solution is needed in the learning process to overcome physics problem solving skills. Teachers as educators are expected to be able to design learning models that can support the improvement of students' abilities so that they can solve a problem. Based on some research results that have been read, the Missouri Mathematic Project Learning Model can be used to improve problem solving skills. Missouri Mathematics Project (MMP) model is a mathematics learning model. The MMP learning model can support the improvement of students' mathematical problem solving skills caused by one-way learning (Berutu et al., 2022). The MMP learning model is one of the models designed to maximize the effectiveness of learning in assisting teachers through exercises so that students have good learning outcomes. The exercises are controlled exercises and independent exercises (seat work) (Badiah, 2023). The MMP learning model contains five stages, each of which has certain objectives to be achieved (T. T. Lestari & Warni, 2023), namely review, development, practice with the teacher, independent work and assignments. Based on the literature review, the use of the MMP model is more inclined to improve mathematical problem solving skills in the field of mathematics, but is very rarely found in improving physics problem solving skills. In strengthening physics problem solving skills, a strong foundation must be laid in the form of training applied

mathematical knowledge which has an urgency in deepening advanced physics so that the application of mathematics is increasingly important (Högskola & Turner, 2020).

The fact that the relationship between mathematical problem solving ability and physics problem solving ability is very close is used as a basis for implementing the MMP model in the field of physics to improve physics problem solving ability. The stages of the MMP learning model that directs participants to practice in groups and independently periodically, both in the classroom and at home, are one of the hopes of improving students' physics problem solving skills that are not owned by conventional models. Based on the research of Rahmadhani & Yanti (2024), it is explained that high math skills coexist with high physics skills and vice versa. Therefore, referring to the problems described above, the researcher conducted a study with the formulation of the problem, whether the application of the MMP model significantly improved the physics problem solving ability of students compared to conventional learning models. The purpose of this study was to analyze the effectiveness of the MMP learning model in improving the physics problem solving ability of students.

2. METHODS

This study was conducted at Madrasah Aliyah Negeri (MAN) Kota Tanjungbalai. Prior to data collection, the researcher obtained official permission from the school, which approved the research activities on the condition that the confidentiality of the information gathered would be maintained.

The research employed a quasi-experimental design using a nonequivalent control group design. This design includes both experimental and control groups without random assignment. According to Ramdhan (2021), quasi-experimental methods utilize control groups to aid in the research process, though they do not fully control for external variables that may influence outcomes. This method was chosen to observe variables that are prominent and measurable—in this case, students' physics problem-solving abilities.

The nonequivalent control group design allowed the researcher to compare learning outcomes between groups to assess the effectiveness of the Multiple Representation-Based Problem Solving (MMP) model. The study involved two classes: one experimental and one control, comprising a total of 47 students selected from a population of 95 students across four classes. The sampling technique used was purposive sampling, based on prior knowledge of class characteristics provided by the physics teacher. The selected classes were XI MIA 3 (control class, 24 students) and XI MIA 4 (experimental class, 23 students), which were deemed relatively homogeneous in ability.

2.1 Instruments and Data Collection

Two instruments were used in this study: a physics problem-solving test and a student response questionnaire. The test, consisting of five open-ended questions with verbal and visual (image-based) representations, was designed to assess students' problem-solving abilities. The response questionnaire aimed to gauge students' perceptions and attitudes regarding physics problem solving.

Before implementation, both instruments underwent expert validation by two academic experts in physics and physics education. The validation process produced results with validity coefficients ranging from 0.838 to 0.923, indicating a very high validity category. Reliability testing yielded a Cronbach's Alpha of 0.802, also categorized as very high, confirming the instrument's reliability and suitability for research use.

The problem-solving ability test was administered twice: a pretest at the first face-to-face session and a posttest during the fourth session. The assessment was based on a rubric adapted from Docktor and Heller (2009), which includes the following indicators:

1. Problem Description
2. Physics Approach
3. Specific Application of Physics Concepts
4. Mathematical Procedures

5. Logical Conclusions

2.2 Data Analysis

Pretest and posttest scores were analyzed using SPSS version 20. First, a normality test was conducted to determine whether the data were normally distributed. This was followed by a homogeneity test to assess variance equality between groups. Finally, an independent samples t-test was used to compare the mean scores of the experimental and control groups and to determine the effectiveness of the MMP model relative to conventional instruction.

The student response questionnaire served as supplementary data for triangulation, helping to validate and interpret the test results from both the researcher's and students' perspectives. Questionnaire responses were analyzed using percentage analysis to provide a clearer picture of students' engagement and perceptions regarding their physics problem-solving abilities.

3. FINDINGS AND DISCUSSION

The results of the analysis in increasing the physics problem solving ability of students can be seen in table 1.

Table 1. The results of the analysis of the physics problem solving ability of students

Classes	Average Value of Physics Problem Solving Ability		N-gain	Categories
	Pretest	Posttest		
Control Classes	38.67	70.00	0.51	Medium
Experimental Class	36.13	83.43	0.74	Height

The representation of the results obtained on the physics problem solving ability of students has increased. The average score obtained by the control class which was applied to the direct learning model as a conventional model, was seen to increase from an average score of 38.67 to 70.00 with an N-gain value of 0.51 which was in the medium category. The representation of the average results obtained by the experimental class that applied the MMP learning model was seen to increase. The average score obtained was 36.13 to 83.43 with an N-gain value of 0.74, which was categorized as high. The categorization of the N-gain value based on the criteria according to Meltzer in Karinaningsih (2020), namely the high category is in the range of values $0.70 \leq n \leq 1.00$, while the medium category is in the range of values $0.30 \leq n \leq 0.70$ and the low category is in the range of values $0.00 \leq n \leq 0.30$. The results of interpreting the improvement of students' physics problem solving skills in the control class and experimental class can be represented in the diagram in Figure 1.

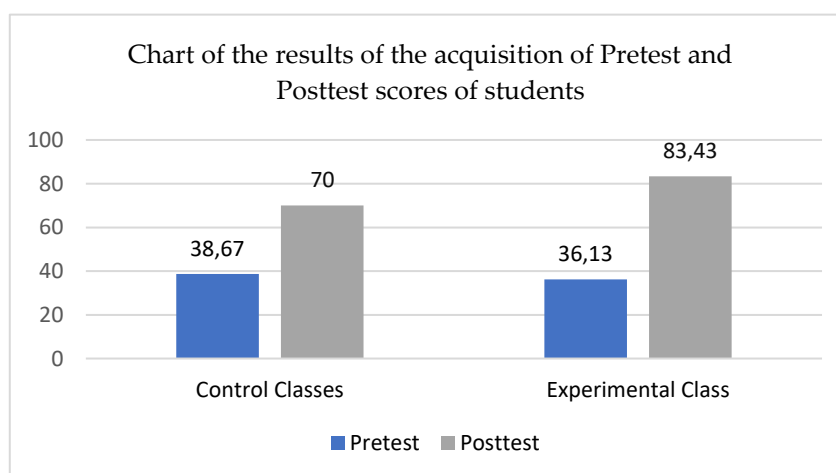


Figure 1. Diagrammatic representation of the improvement of students' physics problem solving skills

Through the results of the diagram representation in Figure 1, it can be seen that the increase in the problem solving ability of students in both classes, namely the control class and the experimental class, has increased but the acquisition of the results of the increase in physics problem solving ability looks very significant in the experimental class applied MMP learning model with the acquisition of scores on the pretest of 36.13 to 83.43 when the posttest is conducted. Unlike the experimental class, the control class also experienced an increase by applying the direct learning model, namely the conventional model obtained pretest results of 38.67 and posttest of 70.00. This increase in the control class looks insignificant when compared to the increase in the experimental class. The increase in students' competence in solving physics problems looks significant in the experimental class can occur due to the implementation of the application of the MMP model in the learning process. The MMP model is a problem-solving and project-oriented model (Nurussobah et al., 2021). This MMP learning model also contains learning stages that are used to assist teachers in the use of group or individual exercises (Kole et al., 2021) so that students are able to construct their own answers based on their experience in solving exercise questions either in groups or independently (Ervinasari & Astuti, 2023). Rizki et al., (2022) said that independent learning can lead to improved problem solving and influence students' maturity in solving a problem.

The next step in testing the hypothesis of the physics problem solving ability of students is to carry out data normality and homogeneity tests. The data normality test in this study used the Shapiro-Wilk test, this is because the sample used in this study was less than 50 ($n < 50$). Data normality and homogeneity tests can be seen in Table 2 below.

Table 2. Hypothesis testing results of the physics problem solving ability of students

Classes	Problem-solving ability scores	Normality*	Homogeneity**	T-test***		Summary
				T-count	T-table	
Control Classes	70.00	0.419	0.079	10.83	2.01	Significant improvements
Experimental Class	83.43	0.310				

Description:

*) : Normality Test, $L_{count} < L_{table}$ (Normal data)

**) : Homogeneous Test, $L_{count} < L_{table}$ (Homogeneous data)

***) : t test, $t_{count} > t_{table}$ (Significant improvement)

The results of the normality test for the control class and experimental class are 0.419 and 0.310. The results of the homogeneity test for students in the control class and the experimental class were 0.079. Obtaining these results for each class is $sig. > 0.05$, so it can be represented that the data obtained is normally distributed and homogeneous. After the normality test and homogeneity test are carried out, the next stage is the average improvement test or t test. The results obtained from the t-test are $t_{count} > t_{table}$ which is $10.83 > 2.01$. This value represents that there is a difference between the two classes. The difference obtained is in the form of physics problem solving competence by students in the experimental class through the implementation of the MMP model, compared to the control class which is implemented by the direct learning model. The MMP learning model is a mathematics learning model that can be used to improve students' mathematical problem solving skills (Fata et al., 2023). This affects the improvement of students' physics problem solving ability because there is an intersection of mathematical problem solving ability with physics problem solving. Based on the literature that inability to learn physics is often associated with deficiencies in mathematics learning (Yuliati et al., 2018), so that students often make mistakes in mathematical calculations (Jannah et al., 2022). The close relationship between these two fields of science creates a situation where students with high levels of mathematical ability will produce high physics abilities as well (Badmus & Jita, 2023).

The MMP Learning Model is implemented in order to direct students to be able to solve problems in various ways. The MMP model has stages, namely review, development, controlled practice, independent practice (seatwork), and the assignment stage (Wulandari, 2021).

This stage directs students to be able to build knowledge through exercises provided by the teacher in solving problems. In accordance with constructivism learning theory which emphasizes meaningful learning centered on learners so that learners are able to build their own knowledge through direct experience, reflection and discussion (Salsabila & Muqowim, 2024). A teacher can improve students' poor problem-solving skills by asking students to submit practice problems that are different from the examples given by the teacher and those in the textbook (Anggraeni et al., 2023). This can be said to be a form of independent practice given by the teacher to students. I. F. Lestari, (2023) stated that teacher guidance is also very necessary, such as in evaluating problem solving solutions in order to assist students in constructing solutions to problem solving. This can be categorized at the stage of controlled practice with teacher assistance that corresponds to Vygotsky's theory of scaffolding (Kurniasari & Soedjoko, 2014), with all types of forms of assistance provided by teachers to learners called scaffolding (Sarmiento-Campos et al., 2022).

Example problems and practice problems have a use as a habit for students to use the steps of problem solving skills in solving problems which are expected to provide further understanding of the steps in solving problems (Meliana et al., 2022) so that students will become independent learners because they are directly involved in the problem solving process that must be resolved by themselves (Cintami et al., 2024) It can be seen from the positive response of students in table 4 through the application of the MMP learning model which has a good impact on students in the form of being able to describe problems, apply physics approaches, special applications of concepts, mathematical procedures, and conclude logically which results in the creation of active learning. The results of the analysis of the students' response questionnaire on physics problem solving ability can be seen in Table 3.

Table 3. Results of questionnaire data analysis of students' responses to physics problem solving skills

No.	Statements	Learners' opinions			
		Strongly Agree	Agree	Disagree	Strongly Disagree
1.	The application of the MMP learning model makes it easier for me to find information presented in a problem.	65.22	34.78	0	0
2.	After learning by using the MMP learning model (4 meetings) I have a better ability to describe problems in the form of pictures, diagrams and graphs.	91.30	8.70	0	0
3.	I interpret symbols in Physics concepts to solve problems by using the MMP model.	30.43	69.57	0	0
4.	During the learning process in the last 4 meetings, I understood each unit in solving physics problems.	65.22	34.78	0	0
5.	I find concepts or theories that can be used to solve problems.	91.30	8.70	0	0
6.	I determine mathematical procedures and operations appropriately according to the known data.	47.83	43.48	8.70	0
7.	I apply concepts or theories that can be used to solve problems.	47.83	52.17	0	0
8.	I apply mathematical procedures and operations appropriately according to the known data.	43.48	56.52	0	0

9.	I made a conclusion after completing the procedure, mathematical operation and getting the result.	17.39	82.61	0	0
10.	Rechecking all the steps of problem solving is an activity that I always do to end the solution of a given problem.	43.48	52.17	4.35	0
Amount		543.48	443.48	13.04	0
The average		54.35	44.35	1.30	0

Based on the data presented in Table 4, the majority of students in the experimental class gave highly positive responses regarding their experience with physics problem solving. The average percentage of students who selected "strongly agree" was 54.35%, while 44.35% selected "agree". Only 1.30% chose "disagree", and none selected "strongly disagree". These findings indicate that the application of the Multiple Representation-Based Problem Solving (MMP) learning model had a significant positive impact on students' physics problem-solving abilities.

This conclusion is further supported by the results of the physics problem-solving ability test, as well as student responses captured through the questionnaire. Additionally, informal discussions conducted at the end of the lesson revealed further support for the effectiveness of the MMP model. Students provided various positive remarks when asked about the learning model's role in enhancing their problem-solving skills, including responses such as:

"The learning model is good ma'am, so we do a lot of questions. Previously, we rarely practiced so during the exam we were confused about how to answer the exam questions" (Learner 1).

"It's good ma'am, there is a lot of practice, the homework that you give is also good ma'am because there are not many questions so we don't have to do it because there are many assignments from other subjects ma'am" (Learner 2).

The students' responses indicate a clear need for a learning model that emphasizes practice, enabling them to develop their problem-solving abilities both independently and collaboratively. The Multiple Representation-Based Problem Solving (MMP) learning model, originally rooted in mathematics instruction, has demonstrated potential as an effective alternative for enhancing physics problem-solving skills. This is supported by Nissa et al. (2022), who emphasize the foundational role of mathematics in science education. As noted by Hariyadi (2016), mathematical proficiency is essential for mastering physics content, given the strong interconnection between the two disciplines. Nurlailiyah and Deta (2015) further argue that physics problems are inherently mathematical in nature and can often be resolved through mathematical reasoning.

Several critical competencies required for effective physics problem solving—such as identifying appropriate units, performing mathematical operations, and conducting reflective evaluations—are often underdeveloped among students (Darsa et al., 2018). This underscores the relevance of employing a mathematically integrated learning model like MMP to strengthen these skills. As Napis (2018) states, physics problem solving is a high-level cognitive activity that demands not only conceptual understanding but also well-developed skills, knowledge, and sufficient practical experience. Such experience can be fostered through consistent practice, which allows students to construct their own understanding and develop new perspectives for approaching physics problems, supported by their mathematical abilities.

The MMP model also provides teachers with a structured framework for facilitating student learning through practice-based activities. It encourages both individual and group work, allowing students the autonomy to apply their understanding independently, such as through seatwork (Gunadi et al., 2020). By engaging with varied problem-solving tasks, students are better equipped to internalize the learning process and develop transferable problem-solving strategies.

Despite these positive outcomes, the present study has several limitations. One limitation involves the relatively small sample size—only two classes—due to constraints faced by the researcher.

Additionally, the research was conducted in a *madrasah* (Islamic senior high school), where certain practical challenges were encountered. For instance, incorporating homework assignments—a key component of the MMP model—was difficult due to students' pre-existing workloads. As a result, some stages of the MMP model had to be adapted to align with the specific conditions of the learning environment. These constraints may have influenced the overall implementation and impact of the model and should be addressed in future studies.

4. CONCLUSION

The results of this study indicate that the implementation of the Missouri Mathematics Project (MMP) learning model significantly improves students' physics problem-solving abilities, as evidenced by the N-gain score of 0.74 (high category) in the experimental class, compared to 0.51 (medium category) in the control class using conventional methods. This improvement is attributed to the structured stages of the MMP model—such as guided practice with the teacher, independent work, and assignments—that allow students to engage in repeated exercises, thereby strengthening both their mathematical and problem-solving skills. However, the research is limited by the small sample size (only two classes) and the context-specific constraints of the study site, which required adaptations to the implementation of the MMP model, particularly in assigning homework due to students' existing workload. Therefore, it is recommended that future studies involve larger and more diverse samples, and incorporate additional data collection methods, such as interviews or classroom observations, to gain deeper insights into the model's effectiveness and to explore its impact across different educational settings.

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