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APPLICATION OF AN OPEN MATHEMATICAL PROBLEM-ORIENTED PROBLEM-BASED LEARNING MODEL IN INFLUENCING PROBLEM-SOLVING ABILITY AND MATHEMATICAL DISPOSITION

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ABSTRAK

Peningkatan kemampuan pemecahan masalah dan disposisi matematis siswa menjadi sorotan, khususnya pada materi transformasi geometri. Hal ini disebabkan karena model pembelajaran masih menggunakan metode konvensional yang menekankan siswa untuk mengikuti dan menunggu arahan guru. Penelitian ini bertujuan untuk menganalisis keefektifan model pembelajaran berbasis masalah yang berorientasi pada masalah matematika terbuka terhadap kemampuan pemecahan masalah dan disposisi matematis siswa SMA Negeri 1 Susut. Penelitian eksperimen semu dengan desain *posttest-only control group design* dilakukan dengan membandingkan pemberian model pembelajaran PBL dan konvensional. Instrumen yang digunakan berupa tes dan angket. Terdapat 5 butir soal dan 25 pernyataan yang memenuhi kriteria reliabilitas sangat tinggi. Teknik pengumpulan data dalam penelitian ini menggunakan metode tes dan angket. Sampel terdiri dari 60 siswa, masing-masing 30 siswa sebagai kontrol dan eksperimen. Data dikumpulkan menggunakan kuesioner dan dianalisis dengan uji MANOVA ($p<0,05$). Hasil penelitian menunjukkan bahwa penerapan model PBL yang berorientasi pada masalah matematika terbuka secara signifikan lebih efektif daripada model pembelajaran konvensional dalam meningkatkan kemampuan pemecahan masalah dan disposisi matematis siswa baik secara parsial maupun simultan. Penerapan model pembelajaran ini telah meningkatkan ketekunan, minat, dan rasa ingin tahu yang sangat penting untuk pemecahan masalah pada siswa dengan guru sebagai fasilitator.

Kata kunci: Matematika, pembelajaran berbasis masalah, pemecahan masalah, disposisi matematis

ABSTRACT

The improvement in students' problem-solving ability and mathematical disposition is a highlight, especially in geometry transformation materials. This is because the learning model still uses conventional methods that emphasize students following and waiting for the direction of the teacher. This study aimed to analyze the effectiveness of problem-based learning models oriented toward open mathematical problems on the problem-solving ability and mathematical disposition of students in SMA Negeri 1 Susut. A pseudoexperimental study with a posttest-only control group design was conducted by comparing the provision of PBL and conventional learning models. The instruments used are tests and questionnaires. There are 5 items and 25 statements that meet the criteria of very high reliability. Data collection techniques in this study used test and questionnaire methods. The sample consisted of 60 students, 30 each as a control and an experiment. Data were collected using questionnaires and analyzed using MANOVA ($p<0.05$). The results indicate that the application of PBL models oriented towards open mathematical problems is significantly more effective than conventional learning models in improving students' problem-solving abilities and mathematical dispositions both partially and simultaneously. The application of this learning model has led to an increase in perseverance, interest, and curiosity, which are essential for problem-solving with teachers as facilitators.

Keywords: *Mathematics, problem-based learning, problem solving, mathematical disposition*

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Introduction

Mathematics play an important and fundamental role in education. This is because mathematics is a science related to the ability to think and reason, which must be possessed by someone solving the problems faced to increase their ability to think clearly, logically, regularly, and systematically (Fauziah et al., 2017). Therefore, students are expected to possess good mathematical skills, as stated by *Permendiknas* number 22 of 2006. Students' mathematical abilities include problem-solving abilities and mathematical dispositions (Wibowo, 2018). Problem-solving ability refers to students' ability to solve problems mathematically as well as the development of ideas and conceptual understanding. It refers to students' affective aspects in terms of views and approaches used to support problem-solving, including confidence, perseverance, interest, and the ability to think flexibly (Apriliana et al., 2019; Maulana et al., 2022; Purba, 2022). In light of the International Student Assessment Report (PISA) in 2018, it was determined that Indonesia's average mathematics score of 379 was significantly lower than the average score of the Organization for Economic Co-operation and Development (OECD) at 489. This discrepancy suggests that the level of mathematics proficiency among Indonesian students is relatively low and remains at the application comprehension level (Wulandari & Azka, 2018).

The level of mathematical ability still classified as comprehension to application certainly has a negative and significant impact on students' critical comprehension ability and mathematical disposition. Suliantiani et al., 2023) explained that only 4% of students in high school have high mathematical disposition skills. The academic curriculum to which students are exposed often lacks diversity, resulting in monotonous learning experiences. This repetitive nature of learning does not provide students with opportunities to mathematically develop problem-solving abilities. Apriliana et al. (2019) found that, on average, high school students' mathematical proficiency was unsatisfactory. Specifically, only 4% of the students were placed in the very high category, 33.6% were categorized as high, and the remaining 62.4% had a low level of mathematical proficiency. This is in line with the results of a preliminary study conducted at SMA Negeri 1 Susut, Bangli Regency, which showed that most students were not confident, had low curiosity, had no interest in learning mathematics, and had poor problem-solving skills. Kurniawati et al. (2023) explained the main causes of these problems, including the incompatibility of the learning model applied, students' weak understanding and basic concepts, and complex and difficult material.

Another relevant issue raised by Tanjung (2022) is that students tend to be less critical of solving problems mathematically and lack confidence. Lack of self-confidence has a significant impact on students' problem-solving abilities and mathematical disposition. This can hinder their ability to overcome mathematical challenges and affect their interest in and outlook on mathematics. Furthermore, Aini et al. (2020) explained that most students are unable to solve problems related to math. Students tend to have difficulty solving math problems because of a lack of interest in the subject, which affects their motivation to face math challenges. Therefore, it is imperative to undertake measures to enhance students' problem-solving abilities and mathematical dispositions, thereby creating a conducive learning environment that allows them to grasp the materials and lessons taught by teachers.

Modifying the learning process through problem-based learning (PBL) is a viable approach to improving problem-solving skills and mathematical disposition. This alternative teaching model can effectively address the open-ended problems. According to As'ari et al. (2019), the utilization of open problems in mathematics education can have a serious impact on students' activities, mathematical disposition, and problem-solving abilities. This is because open problems provide students with an opportunity to express their ideas, which in turn can increase their confidence. In line with research, Jabarullah & Hussain (2019) state that applying PBL to open problems can foster students' interest in mathematics and improve their ability to solve problems. In light of the information gathered regarding the low levels of problem-solving activities and monotonous learning processes, as well as the low mathematical dispositions observed at SMA Negeri 1 Susut, this study examined the influence of the project-based learning (PBL) model focused on open-ended mathematical problems on the problem-solving abilities and mathematical dispositions of students at the institution. The aim of this research is to contribute to the improvement of learning and problem-solving skills as well as the development of more positive mathematical dispositions in mathematics among students and teachers.

Method

This study used pseudo-experimental research with a post-test control group design (Darwin et al., 2021). This research was conducted at SMA Negeri 1 Susut, focusing on the phenomena and problems that existed in the school. The research took place in the first semester of the 2022/2023 academic year. The population in this study was all grade XI MIPA students at SMA Negeri Susut. The research sample was determined using cluster random sampling of each class X1 MIPA 3 students (30 students) as an experimental class and grade X1 MIPA 2 students (30 students) as a control class (Adnyana, 2021). The instruments used were tests and questionnaires. The data collection technique in this study used a description test method and a questionnaire containing information related to students' problem-solving ability and mathematical disposition. In this study, there were 5 items problem-solving ability items and 25 statements questionnaire statements that met the criteria of very high reliability, namely 0.807 and 0.762, respectively, for the reliability of the problem-solving ability test and mathematical disposition. The questionnaire passed due diligence, including content validity, item validity, and reliability tests (Paulus et al., 2023). This research instrument is presented in Appendix 1 in English.

The hypotheses put forth in this study comprise three distinct parts: first, there are discrepancies between the mathematical problem-solving abilities of students educated via the PBL model focused on open mathematical problems and those taught through conventional learning; second, there are differences between the mathematical dispositions of students educated via the PBL model focused on open mathematical problems and those taught through conventional learning; and third, there are disparities between the problem-solving abilities and mathematical dispositions of students educated via the PBL model focused on open mathematical problems and those taught through conventional learning. All data were tabulated in Microsoft Excel and processed using the MANOVA test with SPSS 20.00. PC for Windows. Decision-making and 95 a confidence level (p <0.05). All the data are presented in the form of tables and narratives.

Result and Discussion

A. Result

1. Descriptive analysis

Based on the findings of the study, students who were taught using the Project-Based Learning (PBL) model oriented towards open mathematics problems, achieved an average score of 13.50 on problem-solving ability, whereas students in the control group who were taught using conventional learning methods obtained an average score of only 11.13. Furthermore, the average score for students' mathematical disposition in the experimental class was 99.13, whereas it was only 89.93 in the control class. These results suggest that the PBL model is more effective than conventional methods in promoting student learning, including mathematical disposition. Table 1 presents a descriptive analysis of the students' problem-solving abilities and mathematical dispositions.

Table 1. Data description mathematical problem-solving ability and disposition capabilities

Statistics \ Group	A_1Y_1	A_2Y_1	A_1Y_2	A_2Y_2
Multiple Samples	30	30	30	30
Mean	13,50	11,13	99,13	89,53
Median	14,00	11,00	99,50	87,00
Standard Deviation	3,38	3,27	10,41	13,07
Varians	11,43	10,67	108,46	170,740
Score Maximum	19	18	120	112
Score Minimum	7	5	83	65

Description: A_1Y_1= students' problem-solving ability with the open-math problem-oriented PBL model, A_2Y_1= students' problem-solving ability with the conventional model, A_1Y_2= students' mathematical disposition with the open-math problem-oriented PBL model, A_2Y_2= students' mathematical disposition with the conventional model.

2. Prerequisite Testing

Prior to confirming the research hypothesis, the data collected must meet mandatory prerequisites, including normality, multivariate normality, homogeneity, and variance–covariance matrix homogeneity. The results of the Kolmogorov–Smirnov test revealed that for the experimental class problem-solving ability test score data, control class problem-solving ability test score data, experimental class disposition questionnaire score data, and control class disposition questionnaire score data, a probability value of 0.200 (p>0.05) was obtained. Therefore, it can be concluded that data on students' problem-solving abilities and mathematical dispositions were normally distributed. The results of the normality tests are presented in Table 2.

Table 2. Data normality test results

Data	Class	Kolmogorov–Smirnov		
		Statistic	df	Sig.
Test Scores	Experiment	.125	30	.200*
	Control	.131	30	.200*
Poll Score	Experiment	.122	30	.200*
	Control	.116	30	.200*

Based on the results of the testing for multivariate normality, the scatter plots display points that follow diagonal lines that are not randomly dispersed. Therefore, it can be inferred that the residual data pertaining to students' problem-solving abilities and mathematical dispositions conform to a normal distribution in a multivariate context. The test results are shown in Figure 1.

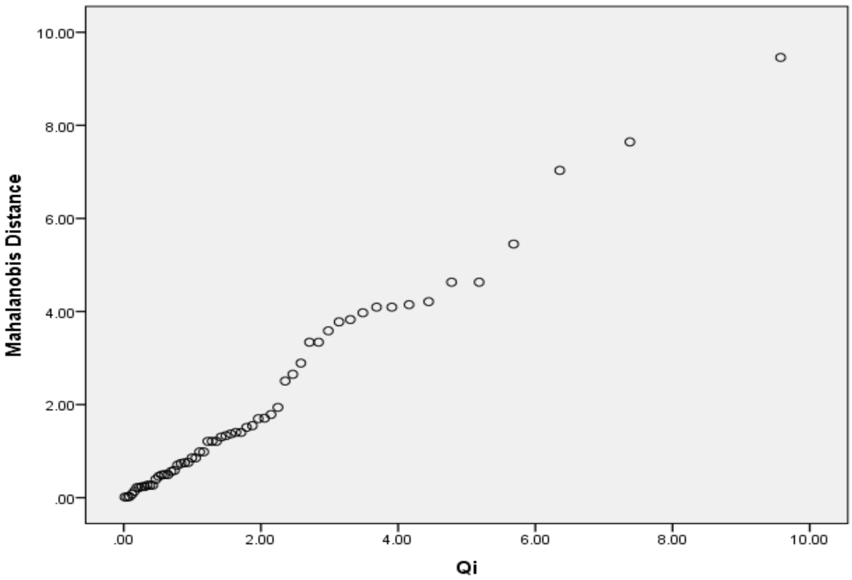

Figure 1. Multivariate normality test results with scatter plot

Further tests were performed by using the Mahalanobis distance test. The results showed a *Pearson* correlation coefficient of 0.992 (p>0.05). Thus, it can be stated that there is a correlation, or, in other words, multivariate normally distributed data. The results of multivariate normality testing with correlation analysis are presented in Table 3.

Table 3. Multivariate normality test results with correlation analysis

Correlations			
		Mahalanobis Distance	Qi
Mahalanobis Distance	Pearson Correlation	1	.992**
	Sig. (2-tailed)		.000
	N	60	60
Qi	Pearson Correlation	.992**	1
	Sig. (2-tailed)	.000	
	N	60	60

For prerequisite testing, Levene's test of equality of error of variance was conducted to evaluate the homogeneity of the data on problem-solving ability (test score) and mathematical disposition (questionnaire score). The results showed significance values of 0.693 and 0.171, respectively (p>0.05). Therefore, it can be inferred that the data on students' problem-solving abilities and mathematical disposition originated from homogeneous or similar variance. The results of the variance homogeneity test are presented in Table 4.

Table 4. Variance homogeneity test results

Test of Homogeneity of Variances				
	Levene Statistic	df_1	df_2	Sig.
Test Scores	.158	1	58	.693
Poll Score	1.903	1	58	.173

Based on the results of the variance–covariance matrix analysis using Box's M test, a statistically significant result of 4.108 was obtained, with a p-value of 0.271. With a significance level set at α=0.05, the null hypothesis that the variance-covariance matrix of the dependent variable is equal cannot be rejected, as the p-value (0.271) is greater than the significance level (α=0.05). The results of the variance-covariance matrix homogeneity tests are presented in Table 5.

Table 5. Variance–covariance matrix homogeneity test results

Box's Test of Equality of Covariance Matrices[a]	
Box's M	4.063
F	1.304
df_1	3
df_2	605.520.000
Sig.	.271

3. Hypothesis Confirmation

A meticulous analysis of problem-solving aptitude and mathematical inclination was conducted to determine their suitability as prerequisites for the MANOVA examination, which mandates that the normality and homogeneity tests be met. Subsequently, a series of further assessments were conducted to confirm the validity of this premise. Upon verification of the first hypothesis, a problem-solving assessment score was obtained with a statistically significant value of 0.008 (p<0.05), indicating discrepancies in mathematical problem-solving proficiency between students who are educated using the problem-based learning (PBL) model that focuses on open-ended mathematical problems and those trained using conventional teaching methods. Similarly, the second hypothesis was corroborated through the procurement of a mathematical disposition questionnaire score with a statistically significant value of 0.003 (p<0.05), indicating that there are distinctions in mathematical inclination between students educated using the PBL model that focuses on open-ended mathematical problems and those trained using conventional teaching methods. Table 6 for the hypothesis testing results.

Table 6. Results of the first and second hypothesis tests

Tests of Between-Subjects Effects						
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	skor_tes	84.017[a]	1	84.017	7.603	.008
	skor_angket	1382.400[b]	1	1.382.400	9.902	.003
Intercept	skor_tes	9.102.017	1	9.102.017	823.626	.000
	skor_angket	533.926.667	1	533.926.667	3.824.627	.000
Kelompok	skor_tes	84.017	1	84.017	7.603	.008
	skor_angket	1.382.400	1	1.382.400	9.902	.003

The results of testing and confirming the third hypothesis have revealed F values for Pillai's Trace, Wilks Lambda, Hotelling's Trace, and Roy's Largest Root, which are all significant at a level of 0.011 ($p<0.05$). This suggests that there are significant differences in problem-solving abilities and mathematical dispositions between students taught using the Problem-Based Learning (PBL) model focused on open mathematical problems and those taught using conventional learning methods. Table 7 presents the results of the analysis.

Table 7. Results of the third hypothesis test

Multivariate Tests[a]						
Effect		Value	F	Hypothesis df	Error df	Sig.
Group	Pillai's Trace	.146	4.874[b]	2.000	57.000	.011
	Wilks' Lambda	.854	4.874[b]	2.000	57.000	.011
	Hotelling's Trace	.171	4.874[b]	2.000	57.000	.011
	Roy's Largest Root	.171	4.874[b]	2.000	57.000	.011

B. Discussion

1. Application of PBL model-oriented mathematical problems open to problem solving ability

A formal tone was used in this study. The examination focused on verifying problem-solving abilities in experimental and control classes. The findings indicated discrepancies in mathematical problem-solving proficiency between students who were taught using the PBL model that focused on open-ended mathematical problems and those who were taught using conventional instruction. The more effective the educational model, the better students' mathematical problem-solving abilities. This study discovered that learning with an open-ended math problem-oriented PBL model provides more favorable results than conventional instruction because the open-ended math problem-oriented PBL model at every stage offers opportunities for students to enhance their mathematical problem-solving skills. In lessons utilizing the PBL model directed toward open-ended mathematical problems, the teacher functioned more as a facilitator.

Argaw et al. (2017) explained that the open problem-oriented PBL model offers a variety of opportunities for students to develop their mathematical problem-solving abilities. This approach began by focusing students' attention on open-ended math problems in the early stages of learning. At this stage, students become aware that the material they are about to study has clear relevance and usefulness in their personal contexts (Jabarullah & Iqbal Hussain, 2019). In addition, the use of open mathematical problems in PBL models stimulates student creativity because it allows various problem-solving approaches. Furthermore, this approach creates opportunities for students to engage in discussions and collaborate with other group members (LaForce et al., 2017). This allowed for a deeper exchange of ideas and understanding among the students in the groups.

The open-math problem-oriented PBL model also gives students the opportunity to present the results of their group discussions to their peers, who can later respond to or be improved by other groups. Through social interactions established during this learning process, students can build new knowledge (Ulger, 2018). This approach leads to a deeper understanding of concepts related to a given problem. In the context of learning activities with an open mathematical problem-oriented PBL model, the teacher is more of a facilitator who assists students in directing their learning processes (Rahmaputri, 2020). In contrast to conventional learning, which directly displays definitions and formulas using a mathematical language that already contains variables, students are only able to solve problems in the form of variables using the given steps. Thus, the PBL model is better used than conventional teaching methods at SMA Negeri 1 Susut.

2. Application of PBL models oriented to open mathematical problems to mathematical dispositions

In the present study, a formal tone was appropriate. The findings confirmed a disparity in mathematical disposition between students who were taught using the problem-based learning (PBL) model, which emphasizes open mathematical problems, and those who were educated using conventional methods. Guests in the field showed the average score of the disposition questionnaire based on observations during classroom learning, indicating that students in class with an open math problem-oriented PBL model showed positive things such as perseverance, interest, and curiosity that were high enough to solve problems, confidence when discussing, and presenting. Unlike the case in classes with conventional learning, because the teacher is more dominant in learning, during observation in class students seem to wait only for an explanation from the teacher and answers from the teacher related to practice questions. This causes students to be less confident in their answers and less curious about the material and problem-solving of the questions given.

Additionally, Hidayatsyah et al. (2023) Students who follow learning with a more open problem-based learning approach show better positive attitudes in the mathematics domain than those who engage in learning with a more structured problem-based approach. Students involved in the open-ended mathematical problem-oriented PBL model describe characteristics that reflect a strong mathematical disposition, including a high degree of persistence, deep interest in mathematical subjects, and a high level of curiosity when faced with problem-solving (Liiman et al., 2022). In addition, they showed higher levels of confidence when they participated in group discussions or were asked to give presentations (Ulger, 2018). Meanwhile, in the context of conventional learning, in which teachers play a dominant role, the impact tends to differ. Students in this situation often act only as recipients of information from the teacher and rely on the teacher's explanations and answers related to the practice questions they receive (Jin et al., 2021). This has an impact on students' lack of confidence in their ability to overcome mathematical problems, as well as their low level of curiosity about the subject matter and solving methods contained in the problems they face (Ruhulessin et al., 2019). Thus, a learning approach that promotes open problems in mathematics can be considered an effective strategy for forming strong mathematical disposition in students.

3. Application of PBL models oriented to open mathematical problems to problem solving ability and mathematical disposition

Confirmation was conducted regarding Their ability to solve problems was confirmed, and mathematical dispositions were verified concurrently. The outcomes revealed disparities in problem-solving abilities and mathematical disposition between students who received instruction through the open-ended mathematical problem-oriented PBL model and those taught via conventional learning. Observations during instruction in the experimental and control classes indicated that these concurrent disparities may arise because the PBL model, which focuses on mathematical problems, allows students to cultivate a favorable attitude toward mathematics while improving their problem-solving proficiency. The open problems introduced at the onset of the open problem-oriented PBL step can elicit student interest and spark curiosity about the materials to be covered. When students work in groups or presentations, they can bolster their confidence in solving the given problems and defend their solution methods in front of other groups.

However, because of the advantages of the open problem-oriented PBL model, some difficulties are encountered during learning. At the first meeting of the experimental class, the students were initially very interested because of the problems given but began to become confused when working on LKS because they had not been explained before. Usually, they matched their answers with other group friends; however, their answers were not the same. Finally, the teacher again emphasized that the question is open, allows for various answers and ways, and reminds students to look for sources of knowledge related to the material discussed in various media. In the classroom, the learning control that runs as usual is dominated by teacher activities. Dependence on the teacher is very visible: students listen to the teacher's explanations, take notes, and answer practical questions. For practice questions, students who dare to work in the future are only 3 people without any response from other students. This indicates a lack of confidence and curiosity among students. Thus, the PBL model has its advantages in simultaneously improving students' problem-solving abilities and mathematical disposition.

Project-based learning (PBL) is widely acknowledged for its ability to enhance students' problem-solving skills and instill a positive attitude toward mathematics. From multiple viewpoints, the benefits of this approach can be observed, such as the PBL model, which encourages students to utilize mathematical concepts to resolve real-world problems. This not only renders the educational experience more relevant and engaging but also enables students to understand the practical utilization of mathematics in daily life (Adnyana & Sudaryati, 2022). PBL models often involve complex open-ended problems that require critical thinking and problem-solving skills. Students are challenged to analyze situations, identify relevant information, and develop strategies to solve problems. It assists students in developing essential skills beyond rote memorization (Nufus & Mursalin, 2020; Usta, 2020). Working on projects that are meaningful and interesting to students intrinsically motivates them. This intrinsic motivation can lead to a deeper understanding of mathematical concepts and a more positive attitude toward the subject.

The application of the PBL model encourages student creativity and innovation by exploring various ways to solve problems. This approach fosters a mindset that values multiple approaches to problem solving and realizes that there is more than one solution that can be used in solving problems (Deavy Martyaningrum & Rachmani Dewi, 2018; Gusmaulia et al., 2023; Outside & Classroom, 2023). Learning to use PBL models can contribute to long-term knowledge retention. When students engage with materials in a meaningful context, they tend to remember and understand concepts over time (Benedicto & Andrade, 2022; Eliza et al., 2019; Rijken & Fraser, 2023). One of the key objectives of this learning is to underscore the significance of the PBL model in promoting student autonomy and self-direction. This approach enables learners to assume responsibility for their educational journey by engaging in activities such as problem solving, research, and presentation of findings. This sense of belonging can contribute to a more positive attitude toward learning in general (Nufus & Mursalin, 2020; Outside & Classroom, 2023; Rijken & Fraser, 2023). PBL often involves collaborative work that requires students to communicate and work effectively on teams. This reflects a real-world scenario that prioritizes collaboration. Students learn to articulate their ideas by listening to others and working collectively toward a common goal so that they have equal abilities and minimize inequality between groups (Apriliana et al., 2019; Gusmaulia et al., 2023).

4. Limitations and novelty of research

The material presented in this study is the geometry transformation given to students in the even semester of XI MIPA. This study focuses on the application and testing of concepts in geometric transformation of materials. Meanwhile, the scope of this study is limited to SMA Negeri 1 Susut schools; therefore, the data collected are contextual and do not represent variations that may exist in other schools. This research has demonstrated the benefits of utilizing a PBL model focused on open mathematical problems to enhance students' problem-solving skills and attitudes towards mathematics. The results of this study can serve as a valuable reference for high-school mathematics teachers seeking to implement innovative instructional practices.

Conclusion

The PBL model oriented toward open mathematical problems had a positive and significant effect on the problem-solving ability and mathematical disposition of Class XI students in the SMA Negeri 1 Shrinkage on geometry transformation material. The application of problem-based learning models oriented to open mathematical problems is superior to conventional learning models in improving students' problem-solving abilities and mathematical dispositions both partially and simultaneously. Utilizing Problem-Based Learning (PBL) models in an educational setting is highly beneficial because it encourages creative thinking by allowing for various approaches to problem-solving. Furthermore, this model enabled students to present group discussions with their peers, thereby providing opportunities for feedback and improvement. Through these social interactions, students can construct new understanding and improve their problem-solving abilities and overall mathematical disposition. Further research is needed to compare learning models in different schools and identify accompanying predispositions related to student changes in the learning process.

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