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Effectiveness of Implementing Open Source-Based E-Learning Media "Mathematics Laboratory: SPLDV" on Mathematical Problem Solving Skills of MTs Students in Tangerang Regency

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Abstract: Technology-based learning media is an important tool in supporting interactive and adaptive learning processes in the digital era. This study aims to evaluate the effectiveness of open source-based e-learning media "Mathematics Laboratory: SPLDV" in improving students' mathematical problem-solving abilities at MTs Negeri in Tangerang Regency. The media used is designed to facilitate interactive learning of concepts and applications of the Two-Variable Linear Equation System (SPLDV) in everyday life. The method used is a pre-experiment with a one-group pretest-posttest design, where one group of students is given a pretest, then given treatment using e-learning media, and ends with a posttest. The subjects of the study were grade IX students of MTs Negeri in Tangerang Regency. Data were collected through problem-solving ability tests. The results of the analysis show that open source-based e-learning media "Mathematics Laboratory: SPLDV" can improve students' mathematical problem-solving abilities, seen from the N-Gain percentage of pretest and posttest data of 60.815% which is included in the fairly effective category. This study is expected to provide an alternative for educators in integrating learning technology to improve students' problem-solving abilities in mathematics.

Keywords: Effectiveness; E-learning; Mathematics; Open-source; Problem solving

Introduction

Mathematical problem solving ability is an important skill that students must have in facing the challenges of learning mathematics in the modern era (Ariatman & Arifin, 2024; Cynthia & Sihotang, 2023). This competence does not only refer to students' ability to solve mathematical problems, but also their ability to think critically, analytically, and creatively in solving complex problems.

In the 21st century, problem-solving skills have become one of the competencies that are greatly needed in the world of work (Ameliasari & Wilujeng, 2023; Ramadhan & Diana, 2022). Rapid technological advances and global change demand a workforce that not only has theoretical knowledge, but is also able to analyze, evaluate, and find solutions to various complex challenges (Amaliah et al., 2021). Many fields of work, such as science, technology, business, and the creative industry, require individuals who can think critically and find innovative ways to solve problems. In addition, this ability also plays a role in increasing work productivity and effectiveness, because individuals who are able to solve problems well tend to be more adaptive to change and are able to make the right decisions in uncertain situations (Djunaidi & Alfitri, 2022).

Problem solving ability is one of the aspects emphasized in the national education curriculum

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(Sukarso & Lestari, 2024; Kawuwung & Mamahit, 2023) because it has a strategic role in developing students' logical thinking and decision-making skills. Although important, students' mathematical problem solving abilities at the Madrasah Tsanawiyah (MTs) level are still low (Adifta et al., 2020). Problem solving ability is an important foundation in mathematics learning at the next level (Agustina et al., 2024; Makki et al., 2024), because it helps students understand concepts more deeply and apply them in various situations (Pramita et al., 2022). If this ability is low, students tend to have difficulty in solving exam questions that require critical and analytical thinking. In addition, limitations in problem solving can also have an impact on daily life (Hadi et al., 2023; Permata et al., 2021), such as in financial calculations, decision making, or solving other practical problems. Therefore, strengthening these skills from an early age is very necessary so that students are better prepared to face academic and real-life challenges. This phenomenon shows the need for innovation in learning methods and media that can improve students' problem-solving skills effectively.

The System of Linear Equations in Two Variables (SPLDV) is one of the important materials in mathematics taught at the Madrasah Tsanawiyah (MTs) level. This material plays a role in training logical thinking and problem-solving skills, which are very necessary in advanced mathematics learning and in everyday life. SPLDV is used to solve various problems involving two variables, such as financial calculations, business planning, and data analysis. However, despite its importance, many students have difficulty understanding this concept because they have to translate the problem into a mathematical equation and determine the right solution method, such as substitution, elimination, or graphing.

The main difficulty in learning SPLDV lies in problem-solving skills, where students must analyze information from story problems and turn it into a mathematical model. Some students have difficulty understanding the relationship between variables, performing calculations correctly, and choosing the most effective strategy to solve problems. Therefore, a more contextual and interactive learning approach is needed, such as the use of digital media, and gradual exercises. With the right strategy, students can more easily understand SPLDV, improve critical thinking skills, and be more confident in solving math problems and facing challenges in the real world.

One effort to overcome the problem of low problem-solving skills in students is to apply learning models (Arifin et al., 2024) and utilize technology in learning, one of which is through digital learning via e-learning. The e-learning platform allows students to learn more flexibly, independently, and interactively with various learning resources available digitally (Suwandi et al., 2021). Through e-learning, students can access more varied materials, such as learning videos, simulations, and case-based practice questions, which can train critical thinking and problem-solving skills. In addition, technology also allows teachers to provide feedback more quickly and personally (Trianawati et al., 2023), so that students can better understand their mistakes and find more effective solutions.

The use of technology in learning has been shown to have a positive impact on improving student learning outcomes, including in mathematics learning (Mattawang & Syarif, 2023). One potential form of technology integration is the application of open source-based e-learning media (Susilawati & Aris, 2020), which is not only widely accessible to students and teachers but also flexible in adjusting to specific material and curriculum needs. E-learning Mathematics Laboratory: SPLDV is one example of open source-based e-learning media that has been developed to help students understand the concepts and skills in solving the Two Variable Linear Equation System (SPLDV), which is one of the important materials in mathematics at the MTs level (Fajri et al., 2024). This media has been designed with an interactive interface and adaptive learning modules to facilitate students in understanding the basic concepts of SPLDV and applying them in the context of problem solving and has been validated for both content validation and construct validation.

The following is a display of the dashboard and my course on the e-learning "Mathematics laboratory: SPLDV", which is presented in Figure 1 and Figure 2.

This study aims to test the effectiveness of the use of e-learning media Mathematics Laboratory: SPLDV in improving the mathematical problem-solving abilities of MTs students on the material of Two-Variable Linear Equation Systems. In this context, the effectiveness of e-learning media is measured based on the improvement in student learning outcomes (Volunteer et al., 2024), in this case the ability to identify problems, formulate solution strategies, and carry out correct and logical calculation procedures. The application of e-learning Mathematics Laboratory: SPLDV is one of the innovations in e-learning which is expected to be able to provide a more interesting and in-depth learning alternative compared to conventional methods which are often monotonous and do not emphasize the aspect of problem solving as a whole.

The use of open source-based e-learning media not only provides benefits in terms of flexibility and accessibility (Sigit et al., 2022) but also supports independent learning for students. Open source-based applications allow development and updates (Rusli et

al., 2020) so that they can be adjusted to the development of dynamic learning materials and needs. In addition, by utilizing this media, it is hoped that students will be able to learn more independently and understand the concept of SPLDV in a broader and more applicable context, thereby encouraging their problem-solving abilities.

Figure 1. Dashboard view

Figure 2. My course view

This research is important for several reasons. First, it is relevant to the need for interactive and adaptive learning in the digital age, offering an alternative to traditional methods that may be less engaging for students. Second, the use of open source platforms increases the accessibility of learning resources, especially in areas with limited resources. Third, the focus on SPLDV problem solving trains important skills in mathematics. Fourth, targeted interventions on specific topics and groups allow for in-depth analysis. Practically, this research is expected to improve student learning outcomes, inform effective educational practices, evaluate open source resources, and provide context-specific insights for other schools in similar environments.

It is expected that this research can provide real contributions to the development of mathematics learning models at the MTs level in Tangerang Regency. In addition, the results of this study are expected to provide an empirical basis for educators in adopting effective learning technology to improve students' mathematical problem solving abilities. Thus, the application of open source-based e-learning media such as Mathematics Laboratory: SPLDV is expected to be one of the innovative solutions in overcoming the problem of low mathematical problem solving abilities among students.

Method

The research method used was a pre-experiment with a One-Group Pretest-Posttest design. One-Group Pretest-Posttest Design research is a pre-experimental approach used to evaluate the effect of a treatment or intervention on one research group without a comparison group. In this design, researchers measure the target variable before and after the intervention, and the differences in results between the two measurements are analyzed to identify the potential impact of the intervention (Figure 3). The reason for choosing the One-Group Pretest-Posttest design is so that one group gets intensive and planned training so that the results obtained can be maximized (Moon et al., 2024).

The main weakness of the One-Group Pretest-Posttest design is the absence of a control group, making it difficult to isolate the effects of the treatment (e-learning platform) from other factors (Fikri & Adlini, 2023). The increase in posttest scores could be due to the natural maturation of students, external events, the influence of the pretest itself, changes in the test instrument, or regression to the mean (Kawashima et al., 2024). Without a control group for comparison, it is difficult to determine whether the increase is purely due to the e-learning intervention or other factors.

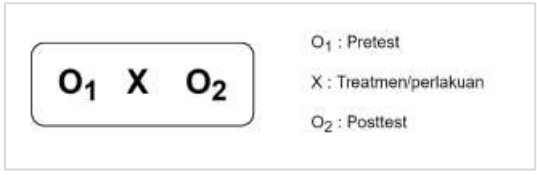

Figure 3. One-group pretest-posttest design

The effect of treatment on this design is O_2-O_1 (Sugiyono, 2011). The thing tested is the difference between O_2 and O_1, if there is a difference where O_2 is greater than O_1 then the application of e-learning mathematics laboratory media: SPLDV has a positive effect on students' mathematical problem solving abilities, and if O_2 is smaller than O_1 then it has a negative effect (Sugiyono, 2009).

The population in this study were all 9th grade students at MTs Negeri in Tangerang Regency. The sample was selected using a purposive sampling

technique, namely 33 students of class 9.6 MTs Negeri 1 Tangerang, 30 students of class 9.1 MTs Negeri 2 Tangerang and 26 students of class 9.1 MTs Negeri 6 Tangerang, with a total sample of 89 students. In this study, purposive sampling was used to select the most relevant sample to the research objective, namely to assess the impact of training on students (Wilson & Anagnostopoulos, 2021).

The selection of classes 9.6, 9.1, and 9.1 from different MTs was based on certain criteria, including similarities in students' academic characteristics that could affect their response to the training. Although these classes come from different MTs, the selection aims to ensure diversity in the selected sample so that the research results can describe the impact of training on students with slightly different backgrounds. Different MTs may have different social or cultural environments so that the effectiveness of training can be tested in a more diverse context. These classes were chosen because they have similar levels of academic ability so that they can reduce external variables that might affect the research results. In addition, the selection of these classes also considers the suitability of the age and academic background of the students, ensuring that students have a sufficient basic understanding of the training material. By selecting these classes, researchers can focus more on evaluating the impact of the training because the students involved already meet the criteria relevant to the research, so that the research results better describe the effectiveness of training on similar groups and can produce more consistent and valid findings.

After the sample is determined, the next stage is to conduct an initial measurement or pretest to determine the baseline conditions of students' mathematical problem-solving abilities before the intervention is given. This pretest is important to determine the extent to which students have mastered the basic concepts in mathematical problem solving (Mahagna et al., 2023), especially in the material on the system of linear equations in two variables (SPLDV), before they are exposed to training using e-learning media. The instrument used for this measurement is a problem-solving ability test that has been carefully designed, and has previously been tested through validity and reliability tests to ensure that the test actually measures what is intended to be measured, and provides consistent and reliable results. Validity testing is carried out to ensure that the questions in the test cover all aspects relevant to SPLDV problem-solving abilities, while reliability testing aims to ensure that the test results can be repeated with similar results, indicating that this test is stable and reliable. Thus, the pretest conducted provides a clear picture of students' initial abilities and becomes a basis for comparison to measure changes in their abilities after the intervention, and helps ensure that the data obtained during the study are accurate and valid.

The next stage is the provision of intervention or treatment to the predetermined group. The type of intervention is adjusted to the purpose of the study, namely the application of e-learning media "Mathematics laboratory" as a learning medium on the material of the system of linear equations of two variables (SPLDV). During this process, interventions are given consistently according to established procedures to minimize the influence of unwanted external variables, such as additional interventions or external interference that can affect the results.

The intervention of using e-learning media “Mathematics laboratory” in learning linear equation system of two variables (SPLDV) was implemented with structured and consistent steps. Students were first introduced to the e-learning platform and given a tutorial on how to access the materials and features. SPLDV materials were presented modularly through text, video, and animation, followed by interactive exercises that provided direct feedback to students. Students were also involved in discussions and group assignments in the e-learning forum to deepen their understanding. During this process, student progress was monitored by the teacher through automatic reporting on the platform, allowing for timely intervention if needed. Evaluation was carried out through online quizzes or exams to measure students’ understanding of the material. All these steps were implemented consistently according to procedures to minimize external interference and ensure the success of the intervention.

After the intervention is completed, a re-measurement or posttest is conducted on the same variables as those measured in the pretest. The results of the posttest are then analyzed and compared with the results of the pretest to evaluate changes or effects that may be caused by the intervention. Statistical analysis, paired sample t-test is used to determine the significance of changes in the variables studied and with the N-gain test it can be identified whether the intervention produces a significant effect. The final stage is the interpretation of the results of the analysis by determining the level of effectiveness of media use (Table 1).

Table 1. Criteria for Determining the Level of Effectiveness (Volunteers et al., 2024)

Percentage (%) N-Gain	Interpretation
<40	Ineffective
40-55	Less Effective
56-75	Quite Effective
≥76	Effective

Result and Discussion

Result

Data Description

The overall data description is displayed from the results of calculations and tests carried out with the help of a computer through the SPSS 22 application program, as well as its analysis and interpretation.

Table 2. Description of Research Data

		Early Score	Final Score
N	Valid	89	89
	Missing	0	0
Mean		12.2135	47.3034
Median		12.0000	47.0000
Mode		12.00	49.00
Std. Deviation		4.71331	8.44555
Minimum		3.00	28.00
Maximum		25.00	65.00

Pretest Score/ Initial Score Data Analysis

The initial score data of students' mathematical problem solving ability obtained from 89 respondents had an average of 12.213 with a standard deviation of 4.713, a median of 12, a minimum score of 3 and a maximum score of 25. The standard deviation score of 4.713, indicates that the difference in answers between respondents is quite high. This shows that the initial scores of the respondents are quite diverse.

From the description it can also be seen that the average value and the middle value (median) are almost the same, namely 12.213 and 12.000. This shows that the initial score data of students' mathematical problem solving ability in this study is quite representative. While the scores above the average are more than those below the average, indicating that the initial scores of mathematical problem solving ability above the average are more than those below the average (Figure 4).

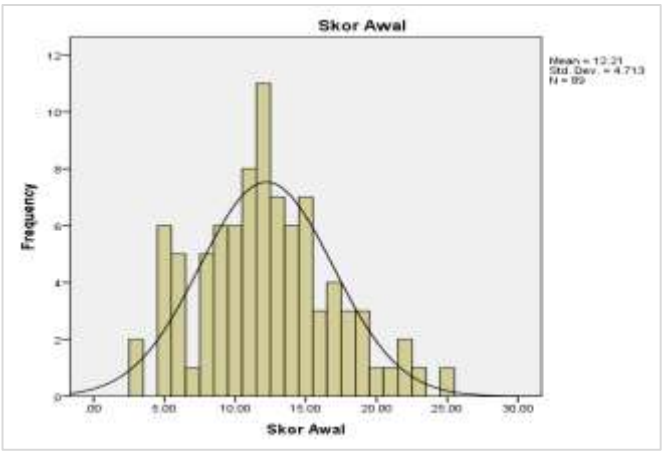

Figure 4. Histogram of initial problem solving ability score data

From the distribution table as well as the histogram and frequency polygon, it can be concluded that the initial score data of students' mathematical problem solving abilities in this study tended to be normally distributed.

Posttest Score/ Final Score Data Analysis

The final score of students' mathematical problem solving ability obtained from 89 respondents had an average of 47.303 with a standard deviation of 8.445, a median of 47.000, a mode of 49.000, a minimum score of 28, and a maximum score of 65. The standard deviation score of 8.445 indicates that the difference in answers between respondents is quite high. This shows that the final score of students' mathematical problem solving ability from respondents varies.

Average and median values are almost the same, namely 47.303 and 47.000 (Figure 5). This shows that the final score data of students' mathematical problem solving abilities in this study are quite representative.

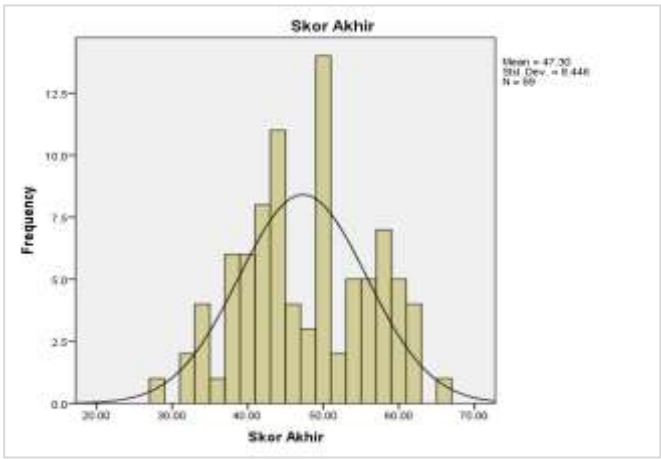

Figure 5. Histogram of final score data for problem solving ability

From the distribution table, as well as the histogram and frequency polygon, it can be concluded that the initial score data of students' mathematical problem solving abilities in this study tended to be normally distributed.

Requirements Analysis Testing

The data analysis requirements testing carried out in this study were normality testing, data homogeneity testing.

Data normality testing

Testing the normality of data for each sample was tested using the following hypothesis:

H_0: the data in the sample is normally distributed.

H_1: The data in the sample is not normally distributed.

The calculation is done with the help of a computer through the SPSS 22 application program. According to the provisions in the program, the criteria for data normality are "if p value (sig) > 0.05 then H_0 is accepted", which means that the data in the sample is normally distributed. The p value (sig) is the number listed in the sig column in the results table or the output of the normality test calculation by the SPSS 22 program. In this case, the Kolmogorov-Smirnov method is used. The calculation results can be seen in Table 3.

Table 3. Recapitulation of Normality Test Results

Tests of Normality

	Kolmogorov-Smirnov [a]			Shapiro Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Early Score	.080	89	.200 *	.982	89	.249
Final Score	.090	89	.070	.980	89	.190

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction.

In Table 3, it can be seen that the value in the Sig column in the Kolmogorov-Smirnov method for all samples is greater than 0.05, so H_0 is accepted, in other words, the data from all samples in this study are normally distributed.

Homogeneity testing

The data on students' mathematical problem-solving ability scores are paired and come from the same respondents, so a homogeneity test is not required.

Paired sample t-test

In the paired t-test output section, there are 3 main tables that we can use to see the characteristics of students' mathematical problem solving data, namely:

Paired Samples Statistics

The Paired Samples Statistics table is used to see the mean difference between students' initial problem solving ability scores and mathematical problem solving. Based on data from the Paired Samples Statistics table, there is a difference between the initial level of students' understanding of 12.213 and the final level of understanding of 47.303 after implementing the open source-based e-learning media "Mathematics Laboratory: SPLDV". However, to ensure the significance of this difference, further analysis is needed to determine whether the difference is statistically significant or not.

Table 4. Output Paired Samples Statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Early Score	12.2135	89	4.71331	.49961
	Final Score	47.3034	89	8.44555	.89523

Paired Samples Correlations

The Paired Samples Correlations table explains the correlation or relationship between students' mathematical problem solving data before and after learning.

Table 5. Output Paired Samples Correlations

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Early Score & Final Score	89	.300	.004

The results of the analysis show that there is a fairly strong correlation between the initial and final understanding of students. This is indicated by the Correlation value of 0.300. While the sig. value (0.004) <0.05. So the correlation that occurs between students' mathematical problem solving abilities before and after learning is significant or meaningful.

So, it can be concluded that students' mathematical problem-solving abilities before and after learning have a fairly strong and significant correlation. Thus, our goal of conducting a comparison or difference test using a paired t-test can be continued to the interpretation stage of the Paired Samples Test section.

Paired Samples Test

The Paired Samples Test table is a table that we can use to ensure whether differences in students' mathematical problem-solving abilities occur in real (significant) ways or not.

Table 6. Output Paired Samples Test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2 tailed)
Pair 1	Start Score - Final Score	-35.08989	8.34844	.88493	-36.84850	-33.33127	-39,653	88	.000

The results of the analysis show that the Sig. (2-tailed) value = 0.000 < 0.05. This means that there is a meaningful or significant difference between students' mathematical problem solving abilities before and after

using open source-based e-learning media "Mathematics Laboratory: SPLDV".

Based on the results of the difference test using the Paired-Sample T-test between the mathematical problem solving abilities of early and late students, it can be concluded that there is a significant difference. Therefore, the analysis of changes/improvements in student learning outcomes can be continued using the N-Gain Test.

N-Gain Testing

The N-Gain score ranges from -1 to 1. Positive values indicate an increase in student learning outcomes after learning, while negative values indicate a decrease in student learning outcomes. With the calculation of SPSS 22, the output description of %N Gain is obtained as in Table 7.

Table 7. Descriptives Output NGain_Percent

Description				
			Statistics	Std. Error
NGain_Percent	Mean		60.8157	1.48604
	95% Confidence Interval for Mean	Lower Bound	57.8625	
		Upper Bound	63.7689	
	5% Trimmed Mean		60.6645	
	Median		58.4615	
	Variance		196.541	
	Std. Deviation		14.01929	
	Minimum		36.84	
	Maximum		91.53	
	Range		54.68	
	Interquartile Range		21.29	
	Skewness		.124	.255
	Kurtosis		-.946	.506

Open source based e-learning media "Mathematics Laboratory: SPLDV" at MTs Negeri Tangerang Regency can be seen from the N-Gain percentage. The N-Gain percentage obtained was 60.815%, and was included in the fairly effective category.

Discussion

The results of the research data analysis proven through statistical test analysis with the help of SPSS 22 software show that students' initial mathematical problem solving abilities are normally distributed and the same (homogeneous) with an average value of 12.213. Students' final mathematical problem solving abilities are normally distributed and the same (homogeneous), with an average value of 47.303. The N-Gain percentage is 60.815% with a fairly effective category.

The improvement in problem-solving skills indicates that students actively construct their own knowledge through interaction with materials and activities in the e-learning platform. Interactive e-learning can provide a learning environment that stimulates students to explore, experiment, and find their own solutions, in accordance with the principles of constructivism (Bisri et al., 2021). A significant increase in the average score and N-Gain percentage indicates changes in students' cognitive processes, such as increased conceptual understanding, critical thinking skills, and problem-solving strategies. E-learning can facilitate these cognitive processes through the presentation of structured information, interactive practice questions, and direct feedback in accordance with the principles of cognitive theory.

In each meeting, students are encouraged to be actively involved in building their own understanding. Students do not only receive information from the teacher, but also actively explore concepts independently through various features in e-Learning, such as listening to illustrations or materials, examples of practice questions and practicing quizzes. This activity provides an opportunity for students to better understand the material and increase engagement in class and improve students' mathematical problem-solving abilities. With a more conducive learning atmosphere, students' interest and enthusiasm also appear higher (Zakirman, 2022; Santoso, 2019) and they are more helped in understanding the material because the distribution of the material is not centered on the teacher alone.

The learning culture developed through e-Learning emphasizes the importance of student activeness in exploring knowledge (Anshori, 2017). With a planned activity structure for each meeting, students find it easier to manage their time and learning process (Mulatsih, 2020). This time management is expected to be in line with the use of existing learning facilities, and by itself encourages students to build knowledge independently.

In addition to improving learning outcomes, the use of e-Learning has several advantages that support learning effectiveness. Some positive indicators that are seen include increased student activity in asking questions and presenting assignments that have been completed. E-Learning-based learning also allows students to access wider learning resources (Suryana et al., 2024) so that the assignments given become more varied and encourage creativity. In the process, students also learn to upload assignments independently and explore learning links that can increase their creativity in completing assignments.

The diverse activities in e-learning also increase students' enthusiasm and increase their motivation in learning (Fitriyah & Bisri, 2023). A more dynamic learning atmosphere encourages them to collaborate,

help friends, and solve problems together (Septicasari & Frasandy, 2018). Classes become more lively, and the learning environment becomes more positive and interactive. Over time, this e-Learning method not only enriches students' understanding but also develops the character of sharing, cooperation, and enthusiasm for learning.

Overall, the implementation of open-source e-Learning media "Mathematics Laboratory: SPLDV" has a significant impact on improving students' mathematical problem-solving abilities. Mathematics learning becomes more effective and useful in honing students' mathematical problem-solving abilities. It is hoped that this increase in problem-solving abilities will be an important provision for students to face further academic challenges.

The results of the study by Sulistyaningsih et al. (2022) concluded that the use of E-learning in Mathematics learning with the Problem Posing approach is effective in learning Mathematics on Logic material. The study by Wahyuni et al. (2017) concluded that the effectiveness of developing interactive multimedia modules based on e-learning on the subject of quantities and units in high school obtained an average gain percentage of 67.62 with an effective category. With the many positive results from the use of e-learning as a medium in the learning process, e-learning has become a reference for learning media for teachers in the classroom to continue to use and develop.

Conclusion

The implementation of open-source-based e-Learning media "Mathematics Laboratory: SPLDV" has proven to be quite effective in improving students' mathematical problem-solving abilities. The results of the study showed an increase in n-gain of 60.815%, reflecting that e-Learning helps overcome weaknesses in conventional methods that are often less flexible, while encouraging students to actively learn independently. The development of open source-based e-learning media "Mathematics Laboratory: SPLDV" can be implied by mathematics teachers as one of the technology-based learning media for the Mathematics subject of grade IX, especially in an effort to improve students' mathematical problem-solving abilities in the material of the Two-Variable Linear Equation System (SPLDV). In addition, e-learning "Mathematics Laboratory: SPLDV" also functions as a technology-based learning media that supports the creation of a conducive and interactive learning atmosphere, allowing students to learn independently and explore the material more flexibly. The implication for further researchers is that the results of this study can be the basis for further developing e-learning-based learning media on other mathematics materials, or to examine the effectiveness of using similar media at higher levels of education. Researchers can also explore various additional features in this media, such as gamification elements or adaptation of learning based on student abilities, in order to improve the effectiveness of learning and a more personal learning experience for each student.

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Author Contributions
For this article, the contributions of each author are as follows: RAF is responsible for conceptualization, data collection, data processing, and writing the article. RHP is responsible for conceptualization, writing the article, and reviewing the article. H is responsible for data processing.

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Conflict of Interest
The authors declare no conflict of interest.

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