

IMPROVING MATHEMATICAL PROBLEM-SOLVING ABILITY AND LEARNING INDEPENDENCE THROUGH LIVETWORKSHEETS-ASSISTED PROBLEM BASED LEARNING MODEL ON SENIOR HIGH SCHOOL

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ABSTRACT

Mathematical problem-solving skills and independent learning are essential for facing real-life challenges. In reality, students' abilities in both aspects tend to be low. This research aims to determine the feasibility, practicality, and effectiveness of developing a problem-based learning model assisted by Liveworksheets to improve students' mathematical problem-solving ability and learning independence. The research method used was Research and Development according to the Borg and Gall model, with subjects of 10 students in the limited trial, 30 students in the broader trial, and 60 students in the experimental and control classes. The research instruments included interview guidelines, observation questionnaires, expert validation and response scales, students' learning independence scales, and mathematical problem-solving tests. Data analysis was conducted using descriptive statistical analysis techniques. The results of expert validation showed that the developed product was feasible to use, with a validity score of 94%. The student response averaged 90.33%, and the teacher response averaged 87.3%, indicating that the product was feasible and practical to implement. The statistical analysis of the posttest results showed a significant difference between the experimental and control classes, with a p-value <0.05 (0.001). The N-gain analysis showed that the experimental class experienced a greater improvement, with a gain score of 0.73 compared to 0.55 in the control class. Students' learning independence was higher in the experimental class, with an average score of 77.8% (good criteria). These findings demonstrate that the problem-based learning model assisted by Liveworksheets is feasible, practical, and effective in improving students' mathematical problem-solving ability and learning independence.

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INTRODUCTION

In daily life, humans are never free from problems, especially in today's technological era, where the problems they face are increasingly complex; therefore, students must be equipped with the skills to solve problems. According to George Polya's theory (Nissa, 2015), there are four stages in the problem-solving process, namely: understanding and exploring a problem; finding problem-solving strategies; using strategies to solve the problem; evaluating and reflecting on the solutions obtained. Another opinion is proposed by Daniel Muijs and David Reynolds (Hendriana et al., 2018), who state that there are several stages in solving a problem, namely: "Connecting, Modelling, Scaffolding, Coaching, Articulation, Reflection". By mastering problem-solving ability, students will have critical and creative thinking skills, which are 21st-century skills (Hendriana dkk., 2018). According to Sulistyani et al. (2020) students' ability to solve a problem is not only to measure students' mastery of concepts, but also to measure students' ability to organize strategies or solutions to solve the problem. Abdurrahman stated that mathematics learning can be used as a means to train problem-solving skills (Sapoetra & Hardini, 2020). Furthermore, Nasution and Mujib (2022) stated that there are five basic abilities developed during the mathematics learning process, namely mathematical problem-solving ability, mathematical understanding, mathematical communication, mathematical reasoning, and mathematical connections.

In improving students' mathematical problem-solving ability, it can be supported by developing students' learning independence, which is one of the factors that can influence students' ability in solving mathematical problems (Assyifa et al., 2020). According to Sugandi, students are said to have the ability to learn independently if they have the desire from within themselves to learn independently, can identify their needs in learning, can determine their learning goals, position difficulties in learning as a challenge, and can select or find learning resources and materials that are appropriate to their needs (Sulistyani et al., 2020). Furthermore, Rahayu and Aini (2021) stated that learning independence does not mean that students learn individually, but rather learn with their own desire, are not dependent on others, and are willing to try to solve the problems they face without waiting for answers or assistance from others. This is in line with the opinion of Nasution and Mujib (2022) that learning independence is an attitude of standing on one's own and not depending on others, as well as being aware, active, and initiative-taking in achieving goals. By mastering problem-solving ability and learning independence, students will have a strong foundation to face challenges in the future, both in higher education and in daily life.

However, in reality, students' mathematical problem-solving ability and learning independence tend to be low. According to data from Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) in 2015, it was stated that students from Indonesia tend to have low ability in solving problems, and students' mathematical ability is still low (Lestari et al., 2021). Based on the results of interviews and observations conducted by the researcher on students and teachers in one of the schools in Cianjur, it showed that there are still many students who do not yet have high skills in solving problems; when given practice questions, students appear less enthusiastic in working on them and even tend to cheat from their friends to find out the answers to the given questions, especially students at the upper level who have entered the formal operational stage, where according to Jean Piaget's theory (Herliani et al., 2021), at that age students should already be proficient in problem-solving. The problem of the low ability to solve mathematical problems includes students not yet understanding the problems presented, due to their lack of familiarity with working on non-routine problems. In addition, some students can understand the problem and work according to the steps, but do not recheck their work; thus, the results are less accurate (Sriwahyuni & Maryati, 2022).

This occurs because students assume that mathematics is difficult to learn, so their motivation to learn mathematics tends to be low (Utari et al., 2019) especially at the senior high school level, where the context of mathematics is abstract, which makes it perceived as difficult to learn. In fact, by learning mathematics, students will have the ability to think critically in facing various situations and conditions (Ainurrohimah et al., 2025). One of the materials that is considered difficult by students is the system of three-variable linear equations (SPLTV), although the context can be related to daily life, students tend to be reluctant to solve SPLTV problems because the process is quite long (Benyamin et al., 2021). According to Dewi and Kartini (2021) When students solve the material on the system of three-variable linear equations (SPLTV), students must be able to apply mathematical concepts to solve real-life problems related to SPLTV; thus, this is considered difficult by students. In addition, when students carry out the problem-solving process, they do not check the correctness; thus, the results are less accurate (Sriwahyuni & Maryati, 2022). Furthermore, the results of the analysis by Supartinah and Hidayat (2021) stated that students are confused in determining the method of problem solving and experience errors in solving problems. According to (Dallyono et al., 2025), students' skills in solving a problem are affected by their ability to understand concepts. Many students still have difficulty understanding the step-by-step solution procedures for mathematical problems presented to them. This indicates that students' mathematical problem-solving abilities remain low. As a result, this condition affects the formation of students' independent learning, which has not yet developed.

One of the ways to improve students' mathematical problem-solving ability and learning independence is for teachers to implement innovative learning (Mardiansyah et al., 2025). The problem-based learning model is an innovative learning model in which students are actively involved in solving the problems presented through scientific stages (Pramudita et al., 2023). Sockalingam and Schmidt stated that the characteristics of the problems presented in problem-based learning are aligned with the learning objectives, encourage students to learn independently, make students think critically, condition students to work in groups, foster interest, follow an appropriate format, are clear, encourage elaboration, are relevant, have connections with prior knowledge, and have an appropriate level of difficulty (Zainal, 2022). Furthermore, Simeru et al. (2023) stated that problem-based learning is one of the teaching and learning activities that trains students to find the process of problem-solving scientifically. Problem-based learning uses contextual problems that make it easier for students to understand the problems, thereby stimulating students to organize strategies for solving the problems (SC et al., 2020; Islahiyah et al., 2021).

According to Koesnandar (2020), innovative learning models can be supported by technology, which, when implemented, can address the challenges of the era by equipping students with 21st-century skills, including problem-solving. Furthermore, Haqiqi and Syarifa (2021) conducted a study on the effectiveness of problem-based learning assisted by video and Liveworksheets, which showed a significant improvement in problem-solving ability experienced by students in the experimental class. In addition, the study conducted by Kusumaningrum et al. (2022) showed that there is a significant improvement in problem-solving ability shown by students who learn using online student worksheets.

By considering this, research on the development of problem-based learning assisted by Liveworksheets to improve mathematical problem-solving ability and learning independence of Grade X students needs to be conducted, this is align with Marlina (2020) who stated that teachers need to transform learning activities by developing models that are adapted to real situations and the development of the times to improve the quality of education. This research is an effort to fill the gap left by previous studies by integrating problem-based learning, assisted by the Liveworksheets application, to improve the mathematical problem-solving abilities and

learning independence of Grade X students in schools in the Cianjur Regency. Based on the literature review of previous studies, it was identified that there is a lack of research specifically developing a problem-based learning model assisted by Liveworksheets implemented in the Cianjur Regency area. The objective of this research is to determine the feasibility, practicality, and effectiveness of the development of a problem-based learning model assisted by Liveworksheets in an effort to improve mathematical problem-solving ability and students' learning independence in Grade X on the material of the system of three-variable linear equations. The results of this research are a final product that has been tested for feasibility, practicality, and effectiveness, and is expected to serve as an alternative for mathematics and other subject teachers in carrying out a more effective and innovative teaching and learning process.

METHOD

This study used a development method, or Research and Development (R&D) model Borg and Gall. According to Sugiono (2013), Research and development is a research technique used to produce a particular product and to test the effectiveness of the resulting product. Furthermore, according to Waruwu (2024) the development of the Borg and Gall model is based on needs and problem analysis, and the stages of the model are more complete and comprehensive.

This development research was conducted in one of the senior high schools in the Cianjur area, with the research population being all students in the school. The research subjects were grade X students. The study involved 10 students in the limited trial, 30 students in the extended trial, and 60 students in the produk trial, comprising 30 students in the experimental class and 30 students in the control class. The research instruments included interview guidelines, observation questionnaires, expert validation and response scales, students' learning independence scales, and mathematical problem-solving tests.

Data analysis in this research included two techniques, namely statistical data analysis and descriptive analysis. The data from the feasibility scale questionnaire, in the form of expert validation results and student and teacher response scales, were used to determine that the developed product was feasible and practical. According to Akbar (Slamet, 2022) the criteria for product feasibility assessment based on expert validation were as follows.

Table 1. Product Feasibility Criteria

No	Score Range (%)	Feasibility Criteria
1	$80 < V \leq 100$	Very feasible (can be used without revision)
2.	$60 < V \leq 80$	Feasible (can be used without revision)
3.	$40 < V \leq 60$	Moderately feasible (may be used with revision)
4.	$20 < V \leq 40$	Less feasible (less valid, not recommended for use because a major revision is required)
5.	$0 < V \leq 20$	Not feasible (not used)

Furthermore, the criteria for practicality based on student and teacher response scales were as follows (Hendriko et al., 2024):

Table 2. Practicality Criteria of Response Scale Results

Score	Criteria
86% - 100%	Very practical
71% - 85%	Practical
56% - 70%	Moderately practical
41% - 55%	Less practical
0% - 40%	Not practical

The data from observation results and students' learning independence scales were processed and analyzed using percentages with the following assessment criteria (Safenita et al., 2023):

Table 3. Criteria for Assessing Attitude Scale Results

Score	Criteria
91% - 100%	Very good
61% - 90%	Good
41% - 60%	Fair
11% - 40%	Poor
0% - 10%	Very Poor

The pretest and posttest data from the experimental and control classes were analyzed using IBM SPSS Statistics 26. After obtaining the t-test results from the posttest assessment, the next step was to analyze the data using the N-gain test to calculate the improvement in students' abilities by comparing their pretest and posttest scores. The data from the N-gain analysis were then categorized based on the criteria from Sundayana (Aripin et al., 2021) as follows:

Table 4. N-gain Categories

N-gain value	Category
$g \geq 0.7$	Height
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

RESULTS AND DISCUSSION

Results

This development research was conducted to evaluate improvements in students' mathematical problem-solving ability and learning independence, particularly in the material on the system of three-variable linear equations, using a problem-based learning model assisted by Liveworksheets. The problem-based learning model was designed to encourage students to identify and solve real challenges in a mathematical context, with the expectation that it would improve their problem-solving abilities and enhance their independence in the learning process. During the research, each stage of the development process of this learning model was carried out systematically and in a structured manner to determine the development process of the problem-based learning model assisted by Liveworksheets, the feasibility and practicality, as well as the effectiveness of the problem-based learning model assisted by Liveworksheets in improving students' mathematical problem-solving ability and learning independence.

1. The development process of the problem-based learning model assisted by Liveworksheets

Prototype preparation stage

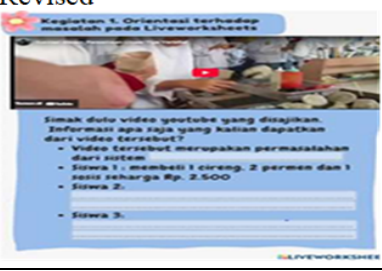
The research activities began by collecting information on the importance of students' mathematical problem-solving abilities and learning independence. Based on the results of the literature review and the background of the problems identified, as well as the results of interviews with mathematics teachers and students, it was identified that students' mathematical problem-solving ability and learning independence in mathematics, particularly on the material of the system of three-variable linear equations, tended to be low, mathematics teachers acknowledged that they had never used the Liveworksheets application in learning, the teaching method was carried out classically, and group learning used worksheets in the form of printed paper.

Based on this, the researcher designed a problem-based learning model assisted by Liveworksheets on the material of the system of three-variable linear equations, to improve students' mathematical problem-solving ability and learning independence. The product designed and developed was the syntax of the problem-based learning model, integrated with the Liveworksheets application. The syntax of the learning activities focused on using the Liveworksheets application. In addition to designing the product, the researcher also developed learning tools, including a learning module, Electronic Student Worksheet (E-LKPD), assessment instruments, and a learning independence scale. The results of the product design, the Student Worksheet (LKPD), the assessment instruments, and the learning independence scale were then reviewed with the supervisor.

Validation Test Stage

At the product validation stage, 3 validators, comprising 2 subject-matter experts and 1 media expert, conducted the validation. Each validator completed a validation questionnaire to assess the product's quality and feasibility. The validators provided several suggestions regarding the product and the Student Worksheet (LKPD) that had been designed. The following are the validators' suggestions, along with the improvements implemented.

Table 5. Suggestions from Subject-Matter Experts and Media Experts

Suggestions	Revisions
Elaborate on the integration of technology in several appropriate stages	The use of Liveworksheets was included in the appropriate syntax
Reduce the use of colors in the Student Worksheet (LKPD)	Revised
	
Use the Liveworksheets template to embed video	Revised
	
Align the activity stages in the Student Worksheet (LKPD) with the learning syntax	Revised

Based on the evaluation results and suggestions from the validators, the syntax of the developed learning model was revised, with the use of Liveworksheets included at the appropriate syntax stages. This change was made to improve the effectiveness and clarity of using Liveworksheets in the learning syntax. The following presents the syntax of the developed learning model before and after revision:

Table 6. Syntax of the Learning Model

Before Revision	After Revision
Orienting students to the problem	Orienting students to the problem in Liveworksheets

Organizing students to learn	Organizing students to learn in Liveworksheets
Guiding group investigation	Guiding group investigation in Liveworksheets
Developing the results of the group investigation and presenting the work	Developing the results of the group investigation in Liveworksheets and presenting the work
Analyzing and evaluating the problem-solving process	Analyzing and evaluating the problem-solving process

After revisions were made to the syntax of the learning model and the Student Worksheet (LKPD), the validation test was conducted twice to ensure the product's suitability and quality, making it feasible for use in the next stage.

Limited trial

During the limited trial stage, the revised product was tested with 10 Grade X students selected at random. These students represented various levels of ability, namely low, medium, and high. Based on students' interview responses and response scales, it was revealed that this was their first experience using the Liveworksheets application. The students stated that the application was easy to access and motivated them to complete the problems in the Student Worksheet (LKPD) because it provided clear, step-by-step guidance. The presentation of the LKPD guided them in finding alternative solutions to the problems presented, as well as in asking questions and engaging in discussion to solve them.

There were several suggestions from the students regarding the display of the Student Worksheet (LKPD) in Liveworksheets: when typing answers into the available columns, the font size was small, and the video was also small, making it less clearly visible. Overall, the Student Worksheet (LKPD) had an attractive appearance. The students were also asked to provide suggestions regarding the readability of the mathematical problem-solving test items and the learning independence scale. They understood the wording of the questions and were able to explain the steps they would take to solve the presented problems, as well as the meaning and purpose of the statements on the students' learning independence scale sheet. After evaluating the limited trial activities, the researcher revised the Electronic Student Worksheet (E-LKPD) in response to student feedback. The revised Student Worksheet (LKPD) was then consulted with the supervisor to obtain further validation. The following are the details of the revisions made after the limited trial.

Table 7. Revisions from the Limited Trial Results

Before Revision	After Revision
 The display of the Student Worksheet (LKPD) video presented in Liveworksheets was not large enough, and the font size when entering answers was small	 The video was presented in a larger size, and the font size for entering answers was adjusted

This revision aimed to improve the quality of the Student Worksheet (LKPD); thus, it was more effective and more aligned with learning needs. This process was carried out by evaluating the results of the expert validation and the limited trial. The following presents a comparison of the initial Student Worksheet (LKPD) before revision and after the final revision to provide a clearer illustration of the changes made to obtain a Student Worksheet (LKPD) that was feasible for use in the next stage.

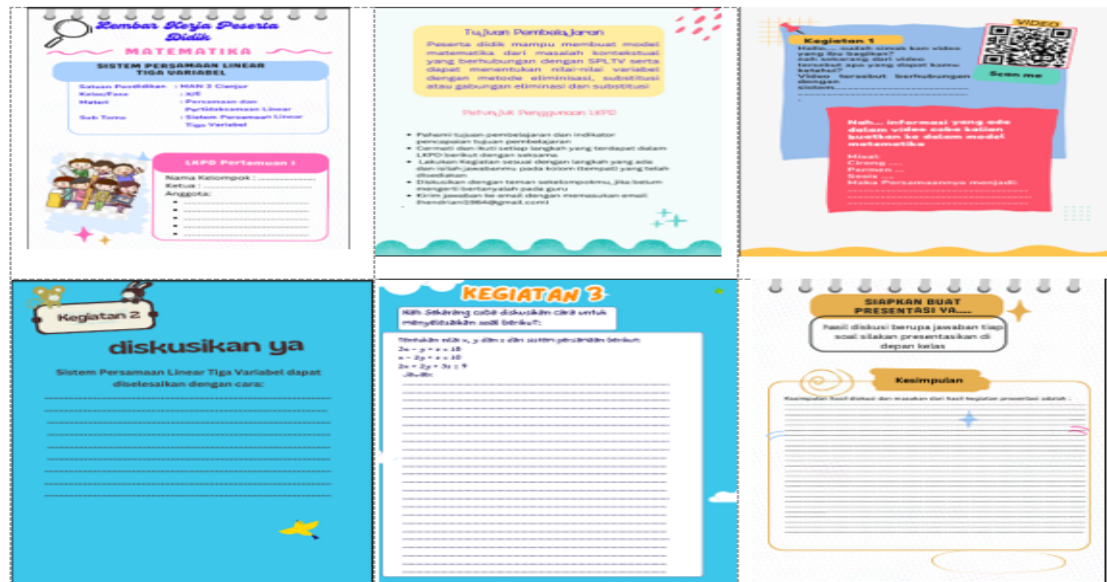


Figure 1. Student Worksheet (LKPD) Display Before Revision

The Student Worksheet (LKPD) displayed before revision used a combination of colors and was equipped with usage instructions and supporting learning videos presented as a barcode. The syntax of the learning activities was not clearly included in the Student Worksheet (LKPD), and the steps for solving problems in the Student Worksheet (LKPD) were not presented clearly. The results of the final revision of the Student Worksheet (LKPD) are as follows:

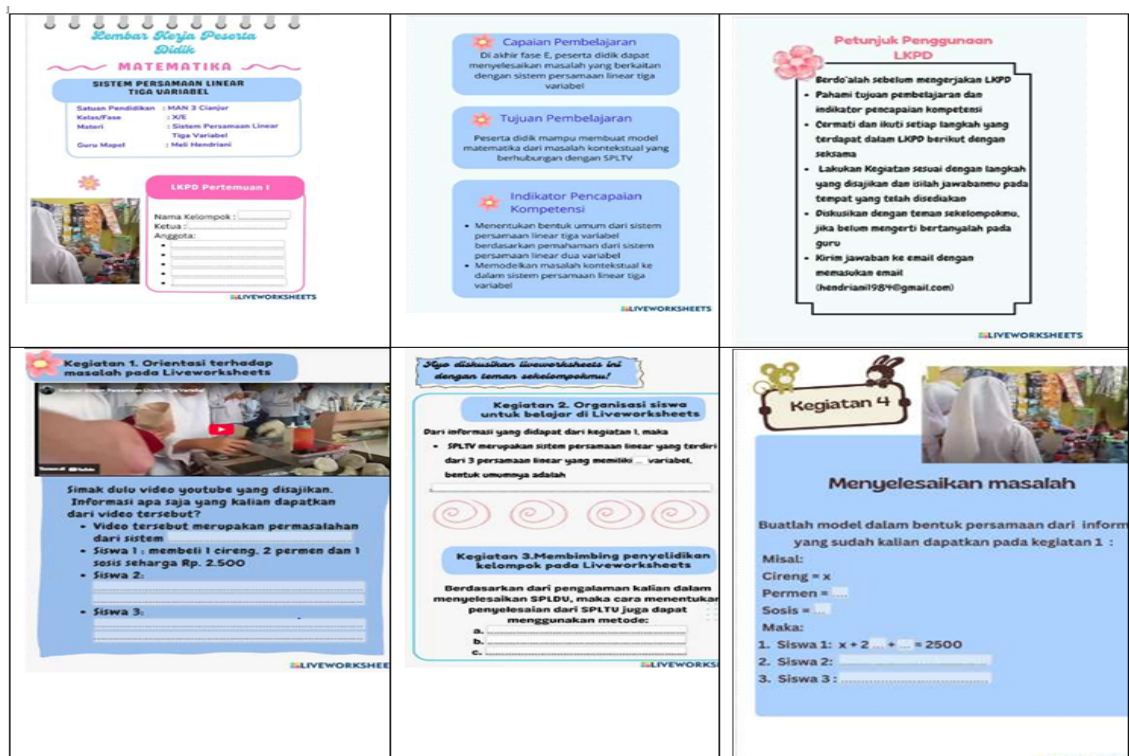


Figure 2. LKPD Display After Revision

Based on several inputs and suggestions from the validators, at the senior high school level, the use of colors did not need to be varied. Then, it was suggested that the videos use the template available in Liveworksheets; thus, students did not need to use other applications to watch the presented videos. Furthermore, each learning syntax was presented and aligned with the activities in the Student Worksheet (LKPD). The revised LKPD used a harmonious color combination to create an attractive display; the LKPD activities were equipped with clear learning syntax; and the videos were presented using the template from the Liveworksheets application. The steps of the learning activities were more structured and clear.

Based on the results of the limited trial activities, the Student Worksheet (LKPD) underwent significant revisions to improve its clarity and effectiveness in supporting the learning process. One of the main changes was increasing the font size in the answer columns. In addition, the videos were presented at a larger size so that students could more clearly see and hear the information. This revision was expected not only to make the Student Worksheet (LKPD) more user-friendly, but also to help students follow the learning activities more effectively by facilitating access to the presented information.

Broad trial

The broad trial was conducted in a single class of 30 Grade X students. The results of interviews conducted during the broad trial activities showed that students felt happy learning with Liveworksheets and were motivated to solve the problems available in the Student Worksheet (LKPD) because the learning steps were provided. Based on the readability results for the mathematical problem-solving test items and the students' learning independence scale, they understood the wording of the questions and the meaning of the statements presented in the students' learning independence scale sheet.

Based on the results of the subject teacher's observation, it was shown that the learning process using the problem-based learning model assisted by Liveworksheets made students active in the learning process; they were enthusiastic in completing the Student Worksheet (LKPD), actively asked questions of the teacher, and engaged in discussions. The following presents the recapitulation of the observation assessment results from the teacher during the learning process.

Table 8. Recapitulation of Observation Results

Aspect	Score Percentage (Meeting)				Average Score	Criteria
	1	2	3	4		
Student involvement and participation in learning	70%	80%	87%	90%	82%	Good
Students' creativity and positive attitude in learning	68%	80%	92%	92%	83%	Good
Overall Average Score	82.5%					Good

According to Table 8, the percentage of students involved in learning met the criteria, with an average score of 82%. In each meeting, student involvement and participation in learning increased. Then, from the perspective of students' creativity and positive attitudes toward learning, it achieved the criteria well, with an average score of 83%. Students' attitudes, assessed in terms of creativity and positive attitudes, increased at each meeting. Even in the 3rd and 4th meetings, they achieved very good criteria, scoring 92%. This indicates that the problem-based learning activities assisted by Liveworksheets positively influenced students' involvement and participation, as well as their creativity and positive attitudes toward the

learning process. Students experienced an adaptive learning process, resulting in changes in attitudes toward a better direction at each meeting.

Product testing

In the product testing phase, the researcher randomly selected two Grade X classes to serve as the experimental and control groups. The experimental class implemented the developed problem-based learning model assisted by Liveworksheets, while the control class continued with the conventional instructional model. Prior to the interventions, both groups were administered an identical pretest to assess baseline mathematical problem-solving ability and the students' learning-independence scale. The instructional interventions were delivered across four meetings covering the topic of three-variable linear equation systems. Upon completion of the instructional period, both groups completed an identical posttest and the students' learning-independence scale. Additionally, students in the experimental class completed a response scale evaluating the developed product. The pretest and posttest scores, the learning-independence scale results, and the experimental-class product responses were systematically analyzed to determine the effectiveness of the developed model in improving students' mathematical problem-solving skills and learning independence. Statistical comparisons between groups and gain analyses were used to evaluate learning gains and effect sizes.

2. The feasibility and practicality of the problem-based learning model assisted by Liveworksheets

To determine the feasibility of the developed product, product validation was conducted by 3 validators, comprising 2 subject-matter experts and 1 media expert. Each validator completed a validation questionnaire to assess the product's quality and feasibility. The results of the validators' assessment showed that the product prototype was feasible to be tested at the next stage with minor revisions. After conducting the evaluation and revision process, the revised product was tested again to obtain validation. The following presents the results of the validators' assessment in validation activities 1 and 2:

Table 9. Expert Validation Results

Category	Validation Result 1	Criteria	Validation Result 2	Criteria
Learning stage design	90%	Very feasible	96%	Very feasible
Learning activities and interaction	90%	Very feasible	90%	Very feasible
Suitability of the learning product	93%	Very feasible	97%	Very feasible
Flexibility and relevance of the product	92%	Very feasible	92%	Very feasible
Average percentage score	91%	Very feasible	94%	Very feasible

Based on Table 9, the validation test results indicate that the developed product met the very feasible criteria for use without revision. In validation activity 1, the product obtained an overall percentage of 91%, while in validation activity 2, the percentage increased to 94%. Furthermore, when viewed from the average score for each statement indicator, it also met the very feasible criteria in both validation stages 1 and 2.

Furthermore, based on the student response scale results from the limited trial, broad trial, and product testing activities, it was evident that the development of the problem-based learning model assisted by Liveworksheets met the very practical criteria. There are two aspects of the student response scale: the usefulness and usability aspects of the developed learning model. The following presents the data analysis of the student response scale results:

Table 10. Student Response Scale Assessment Recapitulation

Aspects	Percentage of Limited Trial Results	Percentage of Broad Trial Results	Percentage of Product Testing Results
Usefulness of the learning model	87%	88%	94%
Usability of the learning model	86%	86%	95%
Average percentage score	86,5%	87%	95%
Overall Average	89,5%		
Practicality Criteria	Very Practical		

In addition to collecting data with a student response scale, the researcher also evaluated the practicality of the developed instructional model by soliciting direct feedback from the mathematics teachers. To that end, the researcher designed and distributed a teacher-specific response scale instrument, which included items addressing the model's instructional syntax, student participation in the learning process, accessibility and effectiveness of learning activities, alignment between lesson content, and students' initiative during classroom activities. the following presents the results of the data analysis from the teacher response scale:

Table 11. Teacher Response Scale Results in the Broad Trial and Product Testing Stages

Aspect	Percentage (Broad Trial)	Percentage (Product Testing)
Syntax of the learning model	80%	90%
Student participation	80%	93%
Accessibility and effectiveness	90%	85%
Relevance of the material	90%	90%
Student initiative	80%	86%
Average score	85%	89%
Overall average	87%	
Criteria	Very practical	

From Table 11, it can be seen that the developed product showed a very high level of practicality. The results of the limited trial averaged 86.5%, while the broad trial reached 87%, and the product testing results 95%; all scores at each stage met the very practical criteria. The overall average score from the limited trial, the broad trial, and product testing was 89.5%, with very practical criteria. Furthermore, based on Table 12, the results of the teacher response scale from the broad trial and product testing reached an average score of 87%, which categorized the very practical criteria, with a practical score of 85% from the teacher response in the broad trial and a score of 89% from the teacher response in the product/field testing. This indicates that the developed product met the very practical criteria and was feasible for use in the learning process.

3. The effectiveness of the problem-based learning model assisted by Liveworksheets

Furthermore, to evaluate the effectiveness of the developed product in improving mathematical problem-solving ability, the pretest and posttest data were analyzed using the IBM SPSS Statistics 26 application. This analysis aimed to identify changes in students' abilities after the implementation of the product. In addition, the data from the students' learning independence scale were analyzed using the percentage scores from the learning independence scale completed by the students after the implementation of the problem-based learning model assisted by Liveworksheets. The following presents the results of the pretest and posttest data analysis.

Table 12. Statistical Description of Pretest and Poster Data Results

Data Statistics	Experimental Class			Control Class		
	Pretest	Posttest	N-Gain	Pretes	Posttest	N-Gain
n	30	30	-	30	30	-
Mean	8,23	46.07	-	8.23	36.42	-
Minimum score	3	31	-	2	12	-
Maximum score	13	60	-	18	58	-
Maximum ideal score	60	60	0.73	60	60	0.55
Normality (Sig.)	0.061	0.118	-	0.124	0.401	-
Homogeneity	0.244	0.124	-	0.244	0.124	-
t-test (Sig. 2-tailed)	1.00	0.001	-	1.00	0.001	-

Based on the analysis of the pretest data results presented in Table 12, it was known that both classes were normally distributed and homogeneous, and showed the same level of ability. This can be seen from the t-test value with a significance (Sig. 2-tailed) of $1.00 > 0.05$. Furthermore, the analysis of the posttest data results also showed that both classes remained normally distributed and homogeneous. Therefore, an independent samples t-test was conducted to determine whether the students' improvement in mathematical problem-solving abilities who were taught using the problem-based learning model assisted by Liveworksheets was better than those taught using conventional instruction.

Table 13. Results of the Independent Samples t-test of the Posttest Scores for Students' Mathematical Problem-Solving Ability

Data Statistics	Value
Sig.	0,124
t	3,445
df	58
Sig. (2-tailed)	0,001
Mean Deference	9,663

When the t-test was conducted using the independent test, a significance value (Sig. 2-tailed) of $0.001 < 0.05$ was obtained. The mean difference was 9.633, indicating that the experimental class achieved higher posttest scores than the control class. These results showed a significant difference in learning outcomes between the experimental and control classes. Consequently, students' mathematical problem-solving abilities who were taught using the problem-based learning model assisted by Liveworksheets were significantly better than those taught using conventional instruction. Based on this, it can be concluded that the developed product was effective in improving students' mathematical problem-solving abilities.

To evaluate improvements in students' mathematical problem-solving ability, pre- and posttest data from the experimental and control groups were analyzed using the N-gain test method. The

results of this analysis provided a more comprehensive description of the impact of the applied learning model on students' abilities. The following presents the results of the N-gain test.

Table 14. Results of The N-gain Test

Group	N-gain Vlaue	Criteria
Experimental Class	0,73	Height
Control Class	0,55	Medium

The results of the N-gain test showed that the improvement in students' mathematical problem-solving ability in the experimental class reached a value of 0.73, which was categorized as high criteria, so it can be concluded that students in the experimental class experienced significant progress in mathematical problem-solving skills after the implementation of the problem-based learning model assisted by Liveworksheets. Meanwhile, the control class, which did not use the learning model, only reached an N-gain of 0.55 with medium criteria. This indicates that although there was an improvement, the achievement was not comparable to that of the experimental class. The results of the N-gain test reinforced that the development of the problem-based learning model assisted by Liveworksheets was effective in improving students' mathematical problem-solving ability.

Furthermore, the results of the data analysis of the students' learning independence scale questionnaire from the experimental and control classes before and after the study can be seen in the following table:

Table 15. Analysis of Learning Independence Scale Results

Indicator	Eksperimen		Criteria	Controls		Sicily
	Before	After		Before	After	
Learning initiatives	56%	77%	Good	58%	60%	Enough
Diagnose learning needs	59%	78%	Good	59%	59%	Enough
Setting learning goals/targets	65%	83%	Good	63%	63%	Good
Viewing difficulties as challenges	61%	73%	Good	57%	57%	Enough
Independent study	62%	78%	Good	60%	65%	Good
Average Presentation	59%	77,8%	Good	59%	60,8%	Enough

From Table 15, it can be seen that students in the experimental class showed better learning initiative, with an average score of 77.8%, compared to the control class, which had an average score of 60.8%. Furthermore, in diagnosing learning needs, the experimental class achieved better results than the control class. In setting learning goals and learning independently, both classes met the criteria, but when viewed by percentage scores, the experimental class had a higher average score than the control class. Based on this, the effectiveness of the development of the problem-based learning model assisted by Liveworksheets positively influenced students' learning independence.

Discussions

The results at the stage of preparing the product prototype through interviews with the mathematics subject teacher showed that the teacher had followed the curriculum developments

implemented by the government; however, the use of technology in the learning process had not been maximally applied, and even the use of the Student Worksheet (LKPD) during the learning process had not been consistent. In addition, the interview results indicated that the teacher faced constraints in the learning process, namely, difficulty in improving students' mathematical problem-solving abilities and fostering independent learning. Based on this, the researcher considered it necessary to develop a problem-based learning model by integrating technology into the learning process in accordance with current developments to improve students' mathematical problem-solving ability and learning independence by using the Student Worksheet (LKPD) in Liveworksheets in the learning process, with the focus of the study being the material on the system of three-variable linear equations.

This transformation aimed to make students more competent in facing the challenges of an era that increasingly relies on technology, according to Choo et al. (Effendi et al., 2021), Student Worksheet (LKPD) is a learning tool designed to help students understand complex ideas through a series of systematic activities. The Student Worksheet (LKPD) that had been designed was then revised to align the steps of the activities with the syntax of the learning model, and to improve appearance by reducing the use of colors without compromising the essence of the presented material. The developed LKPD received positive responses from students. This is evidenced by students' high interest in completing the LKPD activities and their motivation to solve each problem presented. These findings indicate that the LKPD effectively enhances students' interest in learning while also improving their ability to understand the material and solve the problems given. This finding is in line with the results of previous research by Kusumaningrum et al., (2022), which concluded that there is a difference in students' problem-solving abilities between those who learn using online worksheets (LKPD) and those who do not use online LKPD. Then, Setiyaningrum & Sari, (2023) stated that the development of problem-based LKPD can assist teachers in creating a learning process in which students are actively involved in solving the problems.

The development of this problem-based learning model integrated the use of the Liveworksheets application without changing the existing learning syntax, thereby improving students' mathematical problem-solving abilities and learning independence. This is in line with the results of previous research conducted by Aripin et al. (2021) which showed that learning tools based on the problem-based learning model were effective and efficient in improving students' problem-solving ability. They argued that the use of the problem-based Student Worksheet (LKPD) in Liveworksheets was easy to access and very engaging, thereby improving students' learning outcomes (Indriani et al., 2022). In line with this, Pertiwi and Kadarisma (2023) proved that the implementation of the problem-based learning model using the Liveworksheets application had a significant effect on students' learning outcomes; thus, it was able to optimally improve problem-solving ability as well as to foster students' learning independence. The results of the study Sapoeira & Hardini, (2020) show that students' learning outcomes become better when using a problem-based learning model.

The results of the analysis of the research instrument data identified that the development of the problem-based learning model assisted by Liveworksheets was feasible and practical to be used in the learning process, this can be seen from the results of the validation test by 3 experts which showed a final validation score of 93% with very feasible criteria, where each assessed indicator on average obtained very feasible criteria. Furthermore, based on the results of the student response scale, it was identified that students felt happy and motivated to learn using Liveworksheets; they were stimulated to solve the problems presented in the Student Worksheet (LKPD), and the learning steps guided them to engage in discussions in determining problem-solving and discovering the concepts of the material independently. The results of the student response scale yielded very practical criteria, with an overall average score of 89.5%.

Furthermore, based on the teacher response scale, the average score was 87%, with very practical criteria. Therefore, the resulting product was feasible to be used as an alternative learning approach by teachers to meet students' needs in the learning process, because the developed product was adapted to students' needs, where the implementation of the problem-based learning model assisted by Liveworksheets presented problems that occur in daily life, facilitated students to be enthusiastic and actively involved in the problem-solving process, and stimulated students to learn independently.

The feasibility and practicality of the development of the problem-based learning model assisted by Liveworksheets were supported by the results of research conducted by Noormiati et al. (2021), which stated that the use of Liveworksheets in learning made it practical for students to learn independently and facilitated their understanding of the learning material. Furthermore, Paramartha et al. (2024) stated that by implementing a problem-based learning model assisted by Liveworksheets, it could improve student activity in the learning process due to the use of the Student Worksheet (LKPD) in Liveworksheets, which was practical to use, easy to access, and increased student involvement in the learning process.

Furthermore, based on the results of the analysis of the pretest and posttest data, as well as the students' learning independence scale, the developed product was proven to be effective in improving students' mathematical problem-solving ability and learning independence. This effectiveness can be seen from the comparison of the posttest scores between the experimental class that used problem-based learning assisted by Liveworksheets and the control class that used conventional learning as presented in Table 12, viewed from the average posttest score, the experimental class reached 46.07 while the control class reached 36.42, and the minimum score in the experimental class was 30 while in the control class was 12. Furthermore, based on the results of the analysis of the students' learning independence scale, it was identified that students in the experimental class experienced improvement in each indicator of the statements on the presented scale, the percentage scores of each indicator reached good criteria, while in the control class, they reached fair criteria, although two indicators had good criteria. This indicates that the problem-based learning model assisted by Liveworksheets was effective in improving students' mathematical problem-solving abilities and learning independence.

The effectiveness of a problem-based learning model assisted by Liveworksheets in improving students' mathematical problem-solving abilities and learning independence is supported by several previous studies, such as the research conducted by Hurrahma and Sylvia (2022), which stated that the use of STUDENT WORKSHEET (LKPD) based on Liveworksheets was proven to be effective in improving students' learning outcomes and guiding students to learn independently, with a significance test value of $0.00 < 0.05$, indicating a difference in learning achievement after using STUDENT WORKSHEET (LKPD) based on Liveworksheets. Other research results conducted by Sapetra and Hardini (2020) and Pramudita et al. (2023) showed that the problem-based learning model was proven to be effective in improving students' mathematical problem-solving ability, as seen from the improvement in students' learning outcomes. Furthermore, Kusumaningrum et al. (2022) showed that learning using e-worksheets could improve students' mathematical problem-solving ability. Additionally, students' learning activities increased after implementing a problem-based learning model assisted by Liveworksheet, which in turn affected the improvement of students' learning outcomes (Paramartha et al., 2024)

CONCLUSION

Based on the research on the development of the problem-based learning model assisted by Liveworksheets, it can be concluded that the preparation of learning tools must consider students' characteristics and needs. This is important so that the material presented is relevant

and easy to understand, and motivates students to participate actively in the learning process. In addition, the development of learning models needs to be carried out continuously to ensure that the syntax used is aligned with real situations and current developments. Therefore, the learning model can be integrated with technology and the latest learning approaches to be more engaging and effective for students.

With the existence of an adaptive learning model, it can serve as an alternative for teachers in addressing various challenges that arise in the learning process, so that learning objectives can be achieved optimally and students can more easily understand the material being taught. Such as the development of this problem-based learning model assisted by Liveworksheets, which has been proven to be feasible and practical through validity testing and response-scale assessments, making it suitable for use in the learning process. Moreover, it has been shown to be effective in improving students' mathematical problem-solving abilities and learning independence. Therefore, it can be used as an alternative learning model that teachers may apply in an innovative learning process.

The recommendation of this research is that the developed product can be implemented practically in the classroom learning process. Furthermore, improvements are needed in steps considered not yet optimal or effective. By conducting such an evaluation and refinement, this learning product can be used optimally to improve learning quality and support the overall development of students' competencies. The recommendation for future research is to implement the problem-based learning model assisted by Liveworksheets more extensively, either in other educational levels or in different subject areas, in order to determine its effectiveness and suitability across a wider range of learning contexts.

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