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Developing Scaffolding-Based Student Worksheets to Enhance Learning in Systems of Linear Equations in Two Variables

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Abstract:
Mathematics learning requires instructional materials that can support students in understanding abstract concepts and solving problems systematically. However, students often experience difficulties in translating contextual problems into mathematical models and applying appropriate procedures to solve systems of linear equations in two variables (SLETV). This study aimed to develop a scaffolding-based Student Worksheet (LKPD) that is valid, practical, and effective in supporting students' mathematics learning. The study employed a Design Thinking approach consisting of five stages: empathize, define, ideate, prototype, and test. The development process involved a mathematics teacher and ten students. Product quality was evaluated through expert validation, teacher and student response questionnaires, and student learning outcomes. The results showed that the worksheet achieved an average validity score of 97.72%, indicating a very high level of validity. The practicality assessment reached an average of 91.81%, demonstrating that the worksheet was highly practical for classroom use. Furthermore, 80% of the students achieved the established learning mastery criterion, indicating that the worksheet met the effectiveness criterion. These findings suggest that scaffolding-based worksheets can provide structured learning support and help students approach mathematical problems step by step. The developed LKPD offers teachers an alternative instructional resource for facilitating SLETV learning and may serve as a reference for developing similar materials for other mathematical topics.

INTRODUCTION

Education plays a central role in developing human resources capable of responding to social, technological, and economic changes. In this context, mathematics is an essential subject because it develops logical reasoning, problem-solving skills, analytical thinking, and the ability to apply quantitative concepts in everyday situations (Bhardwaj et al., 2025; Furqon et al., 2026). However, mathematics remains one of the subjects that many students perceive as difficult, particularly when learning requires them to connect abstract concepts with contextual problems. One challenging topic is the System of Linear Equations in Two Variables (SLETV), which requires students to understand relationships between quantities, translate verbal situations into mathematical representations,

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and apply appropriate solution procedures (Ahmed Abdel-Al Ibrahim et al., 2023; Bai et al., 2026). The problem becomes more complex when students encounter word problems because successful solutions require conceptual understanding rather than merely memorizing formulas. This condition indicates a broader theoretical gap between the intended development of mathematical competence and learning practices that still emphasize procedural mastery.

The learning difficulties experienced by students also reveal important user needs that should become the foundation for developing instructional materials. Preliminary observations at a junior high school in Probolinggo indicate that students experience difficulties in understanding SLETV concepts, identifying relevant information in contextual problems, determining appropriate mathematical models, and completing solution procedures systematically. (Ahmed Abdel-Al Ibrahim et al., 2023; Wulanningtyas et al., 2024) These difficulties are reflected in limited conceptual understanding and unsatisfactory learning outcomes (Rajab et al., 2026; Sabarudin et al., 2023). From the students' perspective, conventional learning materials may provide insufficient guidance when they encounter difficult stages of problem solving. Monotonous materials can also reduce opportunities for students to explore problems independently, recognize errors, and gradually develop confidence. Therefore, students need learning resources that are understandable, structured, interactive, and responsive to different levels of learning difficulty (Bai et al., 2026; Manaf et al., 2024). Teachers likewise require materials that can provide systematic assistance without making students dependent on direct explanations throughout the learning process.

Addressing these conditions requires an innovative instructional solution that places students' experiences, difficulties, and learning characteristics at the center of development. An effective learning material should not simply present mathematical definitions, formulas, and exercises, but should guide students through a meaningful process of understanding, applying, reflecting, and solving problems (Dermawan & Yusuf, 2026; Dina & Lama, 2025). Such an approach is particularly important for SLETV because students need support in moving from contextual situations to mathematical representations and subsequently to appropriate solution strategies. Instructional materials should therefore accommodate gradual assistance while encouraging students to become increasingly independent (Liskes & van Vorst, 2026; Warli et al., 2026). The development process should also consider how students interact with learning materials, where they experience confusion, what forms of guidance they require, and how support can be reduced as their competence develops. Consequently, a user-centered design process offers a promising foundation for creating learning materials that respond directly to authentic classroom needs.

Design Thinking provides a relevant framework for developing such user-centered instructional innovation because it emphasizes understanding users before designing solutions. Rather than beginning with predetermined instructional products, Design Thinking begins by identifying users' experiences, needs, difficulties, and expectations. Its iterative stages generally involve empathizing with users, defining the central problem, generating possible solutions, developing prototypes, and testing them with users. Applied to mathematics education, this framework can help developers understand the

specific barriers students face when learning SLETV and translate those findings into appropriate instructional features (Nurrahmah & Afnita, 2025; Widarnandana, 2025). The iterative nature of Design Thinking also allows learning materials to be revised based on user responses rather than relying solely on assumptions made by developers or teachers. This approach is particularly relevant to scaffolding because the amount, sequence, and form of assistance can be designed around students' actual difficulties and gradually adjusted toward independent learning.

Previous studies on mathematics learning have demonstrated the potential of scaffolding-based approaches to support students when solving complex mathematical problems. Scaffolding provides temporary assistance through explanations, examples, questions, prompts, clues, or step-by-step guidance, which enables students to perform tasks that may initially exceed their independent abilities (Imai, 2023; Irfan et al., 2026). In instructional materials, scaffolding can be incorporated through carefully sequenced activities that help students understand information, identify relationships, construct mathematical models, and verify their solutions. Previous development-oriented studies have also emphasized the importance of designing learning resources that are systematic, contextual, and aligned with students' cognitive development. In addition, scaffolding strategies have been associated with improved conceptual understanding and problem-solving performance because students receive support at critical stages of learning (Mulyadi Mulyadi Mar'atun Sholihah, Sahrizal Vahlevi, 2025; Suratman & Sugiyono, 2025). Nevertheless, much of the existing work tends to focus on the effectiveness or structure of scaffolding itself rather than explaining how scaffolding materials can be systematically designed from students' needs through an iterative user-centered design process.

Despite these developments, an important research gap remains in the integration of Design Thinking and scaffolding within the development of learning materials for SLETV. Existing approaches frequently begin with predetermined instructional structures and subsequently evaluate their effectiveness, while the voices, experiences, and difficulties of students are not always positioned as the primary basis for product design. This creates a gap between instructional design theory, which emphasizes learner-centered and contextual development, and the practical development of materials that genuinely respond to users' needs. The state of the art of the present study therefore lies in combining Design Thinking as a user-centered development framework with scaffolding as an instructional strategy for supporting gradual mathematical understanding. The novelty is not merely the production of a new worksheet, but the systematic design of a scaffolding-based Student Worksheet (LKPD) through iterative stages of empathy, problem definition, ideation, prototyping, and testing. This integration is expected to produce more relevant and responsive learning materials.

Based on these considerations, this study aims to develop a scaffolding-based Student Worksheet (LKPD) for learning the System of Linear Equations in Two Variables by applying the stages of Design Thinking. The empathy stage is directed toward identifying students' learning experiences, difficulties, and expectations in understanding SLETV. The define stage is used to formulate the central learning problems that require instructional intervention. The ideate stage generates alternative instructional solutions and scaffolding features that correspond to the identified needs. The prototype stage translates the selected

ideas into a structured learning worksheet containing gradual explanations, contextual activities, guiding questions, examples, and problem-solving prompts. Finally, the test stage examines the usability and suitability of the developed product based on user responses and learning needs. Through these stages, the study seeks to produce learning materials that are not only mathematically appropriate but also accessible, responsive, and supportive of students' gradual movement toward independent problem solving.

RESEARCH METHODS

This study employed a Design Thinking approach to develop a scaffolding-based Student Worksheet (LKPD) for learning the System of Linear Equations in Two Variables (SLETV). The development process consisted of five iterative stages: empathize, define, ideate, prototype, and test. The research was conducted at SMP Ihyauddiniyah Probolinggo, located at 5FMR+663, Jl. Masjid Darussalam, Joko'an, Kecik, Besuk District, Probolinggo Regency, East Java, Indonesia. The location was selected because preliminary observations indicated that students experienced difficulties in understanding SLETV, particularly in interpreting contextual problems and applying systematic solution procedures (Revano et al., 2026; SIMANULLANG et al., 2024). The main participants were the mathematics teacher and students, who were directly involved as users of the developed learning product. Data were collected through observations, interviews, needs analysis, document review, expert validation, and prototype testing to identify user needs and provide a basis for designing, refining, and evaluating the LKPD.

The research procedure was conducted iteratively through the five stages of Design Thinking. In the empathize stage, observations and interviews were conducted to understand students' learning difficulties, experiences, and expectations, as well as teachers' instructional needs. In the define stage, the collected information was analyzed to formulate the main learning problems and establish specific user requirements (Lukito & Wijayanti, 2024; Romadona & Karo-karo, 2026). The ideate stage involved generating alternative solutions by integrating scaffolding techniques into the LKPD through explanations, guiding questions, examples, prompts, and gradually reduced assistance. In the prototype stage, the selected ideas were translated into an initial LKPD containing structured activities for understanding and solving SLETV problems. The prototype was subsequently reviewed by experts and revised according to their feedback. In the test stage, the revised LKPD was implemented with students to obtain feedback on its usability and practicality and to collect learning outcome data. Findings from each stage informed subsequent improvements to the product.

The developed LKPD was evaluated in terms of validity, practicality, and effectiveness. Validity was assessed through expert validation involving two material experts and one media expert (Rakhmawati, 2026; Tampa et al., 2026). The validity percentage was calculated by dividing the actual score by the ideal score and multiplying the result by 100%. Practicality was evaluated using response questionnaires completed by the mathematics teacher and students. The practicality percentage was calculated by dividing the obtained score by the maximum score and multiplying the result by 100%. Effectiveness was determined from students' learning test results by calculating the percentage of students who

achieved the predetermined learning mastery criterion. The effectiveness percentage was calculated by dividing the number of students achieving mastery by the total number of students and multiplying the result by 100%. The LKPD was considered effective when at least 70% of the students achieved the predetermined learning mastery criterion. The validity criteria used to interpret the expert assessment results are presented in Table 1.

Table 1. Validity Criteria of the Developed LKPD

Interval	Category
80.00% < AP ≤ 100.00%	Very High
60.00% < AP ≤ 80.00%	High
40.00% < AP ≤ 60.00%	Moderate
20.00% < AP ≤ 40.00%	Low
0.00% ≤ AP ≤ 20.00%	Very Low

Table 1 presents the criteria used to interpret the percentage obtained from expert validation of the developed LKPD. A validity percentage above 80% up to 100% indicates a very high level of validity, while a percentage above 60% up to 80% indicates a high level of validity. The remaining intervals represent moderate, low, and very low levels of validity. These criteria were used to determine the suitability of the LKPD and identify aspects requiring revision based on expert feedback before the product proceeded to user testing.

Data analysis combined thematic analysis of qualitative data with descriptive analysis of quantitative results. Qualitative data obtained from observations, interviews, and user feedback were organized, coded, categorized, and interpreted to identify recurring themes related to students' difficulties, instructional needs, usability, and opportunities for product improvement. Quantitative data from expert validation, response questionnaires, and learning tests were analyzed by calculating the percentages of validity, practicality, and learning mastery. Data validity was strengthened through source triangulation, member checking, and user feedback during each iteration. Source triangulation involved comparing information obtained from students and teachers with observation findings and relevant learning documents. Member checking was conducted by confirming interpretations with participants to ensure that their experiences were represented accurately. Feedback from experts and users was incorporated into subsequent prototype revisions. Through these procedures, the developed LKPD was refined and evaluated as a user-centered instructional product intended to support students' understanding of SLETV.

RESULTS AND DISCUSSION

Results

Product Validity

Product validity was assessed by two material experts and one media expert to evaluate the suitability of the scaffolding-based Student Worksheet (LKPD) for learning the System of Linear Equations in Two Variables (SLETV). The assessment results are presented in Table 2.

Table 2. Validation Results of the Developed LKPD

Validator	Percentage
Material Expert 1	98.46%
Material Expert 2	96.92%
Media Expert	97.78%
Average	97.72%

Table 2 shows that the LKPD obtained validation scores of 98.46% from Material Expert 1, 96.92% from Material Expert 2, and 97.78% from the media expert. The average validation score was 97.72%, indicating that the developed LKPD achieved the very high validity category. The relatively consistent scores across the three validators indicate that the product received highly positive assessments regarding its instructional content and media presentation. These findings suggest that the developed LKPD was considered suitable in terms of its material and media components before being evaluated through teacher and student responses and learning outcome assessments.

Product Practicality

The practicality of the developed LKPD was evaluated using response questionnaires completed by students and the mathematics teacher after their interaction with the learning product. The results are presented in Table 3.

Table 3. Practicality Results of the Developed LKPD

Source	Percentage
Student Response Questionnaire	85.14%
Teacher Response Questionnaire	98.48%
Average	91.81%

Table 3 indicates that the student response questionnaire produced a practicality score of 85.14%, while the teacher response questionnaire yielded 98.48%. The average practicality score was 91.81%, or approximately 91.8%, placing the developed LKPD in the very practical category. Both assessments indicate positive responses toward the learning product, although the teacher's assessment was higher than the students' assessment. The difference between the two scores suggests that the product may be perceived differently by teachers and students in terms of its use during learning activities. Nevertheless, the overall results indicate that the LKPD was considered practical by both groups and could be used as a learning resource for SLETV.

Product Effectiveness

The effectiveness of the developed LKPD was evaluated based on students' test results after participating in the learning activities. Ten students participated in the assessment, and their individual scores and mastery classifications are presented in Table 4.

Table 4. Students' Learning Test Results

No.	Student Initials	Score	Criterion
1	MGR	75	Mastery Achieved
2	NSA	74	Mastery Achieved
3	MT	57	Not Mastered
4	K	94	Mastery Achieved
5	ZF	84	Mastery Achieved
6	I	54	Not Mastered
7	NLM	89	Mastery Achieved
8	AM	94	Mastery Achieved
9	MA	81	Mastery Achieved
10	LH	83	Mastery Achieved

Table 4 shows that eight of the ten students achieved the predetermined learning mastery criterion, while two students did not achieve mastery. The students who achieved mastery obtained scores ranging from 74 to 94, whereas the two students who did not achieve mastery received scores of 57 and 54. The overall learning mastery percentage was 80%, calculated from eight students achieving mastery out of ten participants. Because this percentage exceeded the predetermined minimum criterion of 70%, the developed LKPD met the study's criterion for effectiveness. However, the results also indicate that learning difficulties remained among a small proportion of students, suggesting that the instructional support provided by the LKPD may require further adjustment to accommodate different learning needs.

Discussion

The findings demonstrate that the scaffolding-based LKPD achieved a validity score of 97.72%, indicating a very high level of suitability according to the material and media experts. This finding supports the view that product validity is an essential indicator of whether a developed instructional resource meets its intended educational requirements (Imai, 2023; Revano et al., 2026). Malikah and Jannah (2023) describe validity as a measure of the correctness or appropriateness of a developed product. In this study, the high scores obtained from both material experts and the media expert suggest that the LKPD was considered appropriate in terms of its instructional content and presentation. The consistency of these assessments strengthens the evidence that the product was suitable for subsequent classroom testing. Nevertheless, expert validation primarily establishes the perceived suitability of the product rather than demonstrating learning improvement independently (Romadona & Karo-karo, 2026; Yin & Chen, 2026). Therefore, the validity results should be interpreted alongside the practicality and effectiveness findings to provide a more comprehensive assessment of the developed instructional material.

The practicality results further strengthen the evaluation of the LKPD, with an average score of approximately 91.8%. The teacher's response reached 98.48%, while the student response reached 85.14%, indicating positive evaluations from both groups. However, the difference between these scores deserves attention because teachers and students interact with learning materials from different perspectives. Teachers may prioritize instructional organization, alignment with learning objectives, and classroom implementation, whereas students experience

the clarity of instructions, difficulty of activities, and usefulness of the guidance directly. Although both scores fall within the very practical category, the comparatively lower student response suggests that some worksheet components may still require refinement. These findings highlight the importance of incorporating user feedback into instructional product development. Practicality should not be determined solely by teachers' judgments; students' experiences are equally important because they are the primary users expected to engage actively with the learning activities.

The effectiveness findings indicate that 80% of the participating students achieved the predetermined learning mastery criterion, exceeding the minimum threshold of 70%. This result is consistent with the effectiveness criterion described by Zulfa et al. (2023), which considers a product effective when at least 70% of students achieve learning mastery. The result suggests that the developed LKPD has potential to support students in learning SLETV through structured explanations, guiding questions, and sequential problem-solving activities. Such scaffolding can help students organize information, identify mathematical relationships, and proceed through solution steps more systematically. However, the results also show that two students did not achieve mastery, demonstrating that the product did not address every student's learning difficulties equally (Hou, 2023; Wulanningtyas et al., 2024). Furthermore, because the study involved only ten students and did not report a comparison group or pretest results, the findings establish that the effectiveness criterion was met in this trial but do not conclusively demonstrate that the LKPD alone caused improved learning outcomes.

From a theoretical perspective, these findings contribute to the application of scaffolding principles in mathematics instructional design. Scaffolding emphasizes the provision of temporary support that enables learners to perform tasks that may initially be difficult to complete independently. The high validity and practicality scores, together with the achievement of the predetermined effectiveness threshold, indicate that scaffolding can be translated into a structured worksheet that is considered suitable by experts and positively received by its intended users. In the context of SLETV, this approach is particularly relevant because solving contextual problems requires students to connect verbal information with mathematical representations and procedures. The findings also suggest that the value of scaffolding depends not only on the presence of instructional guidance but also on how that guidance is organized within learning activities (Ahmed Abdel-Al Ibrahim et al., 2023; Rakhmawati, 2026). Nevertheless, the present results provide preliminary evidence of the suitability of this instructional approach rather than definitive confirmation of its theoretical superiority over alternative learning strategies.

The practical implications concern teachers, instructional material developers, and schools seeking to improve mathematics learning. Teachers can use the developed LKPD as a structured resource to guide students through the stages of understanding contextual problems, identifying relevant information, formulating equations, and determining solutions. Its high practicality score suggests that the product may be useful in supporting classroom activities, while the student response results provide a basis for identifying aspects that could be

improved. Developers can use the findings to refine instructions, provide additional examples, and adjust guiding questions to accommodate students with different levels of mathematical understanding. Particular attention should be given to students who did not achieve mastery, as their results indicate a need for additional support or alternative explanations. Schools may also consider integrating scaffolding-based worksheets into broader instructional practices. However, implementation should remain responsive to classroom conditions, and teachers should monitor student progress rather than assume that a validated worksheet will automatically produce mastery for every learner.

The principal contribution of this study lies in providing an empirically evaluated scaffolding-based LKPD for SLETV that demonstrates high expert-rated validity, positive user responses, and achievement of the predefined classroom effectiveness criterion (Lukito & Wijayanti, 2024; Revano et al., 2026). The results offer a practical example of translating scaffolding principles into instructional material that can be evaluated through complementary indicators rather than relying on a single measure of product quality. The study also highlights the importance of considering expert judgment, teacher and student responses, and actual learning outcomes when evaluating educational products. Nevertheless, the findings should be interpreted within the limitations of the small participant group and the absence of a reported comparison group or pretest measurement. Future studies should involve larger and more diverse student populations, examine learning outcomes before and after implementation, and compare scaffolding-based materials with alternative instructional approaches. Further research could also investigate which scaffolding components most effectively support students who continue to experience difficulties with contextual mathematical problems.

CONCLUSION

The findings of this study demonstrate that the scaffolding-based Student Worksheet (LKPD) for the System of Linear Equations in Two Variables (SLETV) achieved a validity score of 97.72%, a practicality score of 91.8%, and an effectiveness rate of 80%, indicating that the developed product was highly valid, highly practical, and effective according to the established criteria. The main lesson from this study is that structured, step-by-step instructional support offers a promising approach to helping students understand mathematical concepts and solve contextual problems. The study contributes to mathematics education by demonstrating how scaffolding techniques can be integrated into instructional materials and evaluated through expert validation, user responses, and student learning outcomes. The practical implication is that mathematics teachers can use the developed LKPD as an alternative learning resource to guide students through interpreting contextual problems, constructing mathematical models, and solving SLETV problems systematically. Theoretically, this study supports the application of scaffolding principles in developing structured learning materials that respond to students' learning needs. However, the study was limited by its small sample of ten students and the absence of a comparison group and pretest measurements, which restrict the generalizability of the findings and the ability to establish causal effects on learning. Future research should involve larger and more diverse samples, compare the LKPD with alternative instructional approaches, and

examine its long-term implications on conceptual understanding and problem-solving skills. Further development could also extend the scaffolding-based approach to other mathematical topics and educational contexts.

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CONFLICTS OF INTEREST

The author confirms that there are no conflicts of interest associated with the research, authorship, or publication of this article.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

ChatGPT was used during the preparation of this manuscript to assist in formulating academic sentences, improving sentence structure, and refining the wording of the article. The author reviewed and revised the AI-assisted suggestions and remains fully responsible for the accuracy, originality, and integrity of the final manuscript.

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