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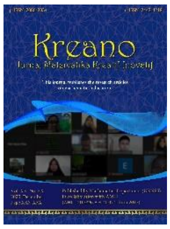

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Development of STEM-Based E-LKPD on Pythagorean Theorem Material on Students' Problem-Solving Ability

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Abstract

Problem-solving ability is a critical component of mathematics education, particularly in understanding Pythagorean theorem concepts. However, current instructional practices often lack integration of STEM approaches and interactive digital tools that support the development of this ability. This study aimed to develop a valid, practical, and potentially effective STEM-based Electronic Student Worksheet (E-LKPD) to enhance students' problem-solving ability. The research employed the ADDIE development model (Analyze, Design, Development, Implementation, and Evaluation) and involved expert validation, practicality testing, and effectiveness assessment with eighth-grade students in a public junior high school following the Merdeka Curriculum. Data were collected through expert validation sheets, student practicality questionnaires, and problem-solving ability tests, then analyzed using descriptive statistics. Results showed that the E-LKPD met validity criteria with an average score of 4.20, reached a practicality level of 85.33%, and demonstrated a positive potential effect, with 57.71% of students achieving a good performance in problem-solving ability. These findings indicate that the developed STEM-based E-LKPD aligns with pedagogical and technological requirements and is suitable for implementation in mathematics learning contexts. This study contributes to digital mathematics pedagogy by offering a contextual STEM-based learning tool supported by interactive technology, addressing current needs in technology-integrated instruction.

Keywords: ADDIE Model; Digital Learning; Mathematical Problem-Solving; Pythagorean Theorem; STEM-based E-LKPD.

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Abstrak

Kemampuan pemecahan masalah merupakan komponen penting dalam pembelajaran matematika, khususnya pada pemahaman konsep Teorema Pythagoras. Namun, praktik pembelajaran saat ini masih kurang dalam mengintegrasikan pendekatan STEM dan alat digital interaktif yang mendukung pengembangan kemampuan ini. Penelitian ini bertujuan untuk mengembangkan Lembar Kerja Peserta Didik Elektronik (E-LKPD) berbasis STEM yang valid, praktis, dan berpotensi efektif untuk meningkatkan kemampuan pemecahan masalah siswa. Penelitian menggunakan model pengembangan ADDIE (Analyze, Design, Development, Implementation, dan Evaluation) serta melibatkan validasi ahli, uji kepraktisan, dan uji efektivitas terhadap siswa kelas VIII di salah satu SMP negeri yang menerapkan Kurikulum Merdeka. Data dikumpulkan melalui lembar validasi ahli, angket kepraktisan, dan tes kemampuan pemecahan masalah, kemudian dianalisis secara deskriptif. Hasil menunjukkan bahwa E-LKPD memenuhi kriteria valid dengan skor rata-rata 4,20, tingkat kepraktisan sebesar 85,33%, dan menunjukkan potensi efektivitas, dengan 57,71% siswa mencapai kategori baik dalam kemampuan pemecahan masalah. Temuan ini menunjukkan bahwa E-LKPD berbasis STEM yang dikembangkan telah sesuai dengan kebutuhan pedagogis dan teknologi, serta layak diterapkan dalam pembelajaran matematika. Penelitian ini berkontribusi terhadap pedagogi digital matematika melalui penyediaan alat pembelajaran kontekstual yang mengintegrasikan prinsip STEM dan teknologi interaktif.

INTRODUCTION

In modern education in the 21st century, students must have high-level thinking skills, especially the ability to solve problems critically, creatively, and systematically. These skills are essential for academic achievement and crucial in the face of increasingly complex global challenges that require data-driven analytical thinking (Rehman et al., 2023). Mathematics education plays an important role in forming the logical, rational, and structured thinking skills needed to solve real-life problems (Monteleone et al., 2023). However, various studies show that students' mathematical problem-solving ability are still relatively low, especially when faced with contextual or non-routine problems that demand deep conceptual understanding. One of the materials that often cause difficulties is the Pythagorean Theorem (Amalina & Vidákovich, 2023; Türkoğlu & Yalçınalp, 2024).

The difficulty students have in solving context-based problems indicates that they are not used to facing problematic situations that demand the application of mathematical concepts in real terms. Systematic literature studies indicate that the learning students have received so far has not involved them in high-level problem-solving activities that reflect daily life situations (Aba-Oli et al., 2024). A more innovative and contextual transformation of learning approaches is needed to bridge this gap. One approach increasingly recognized for its effectiveness is the STEM (Science, Technology, Engineering, and Mathematics) based learning approach, which integrates these four fields into a coherent and applicative learning experience (English, 2023; Lu & Xie, 2024). In this framework, using STEM-based Electronic Learner Worksheets (E-LKPD) is one of the potential solutions that can enrich the learning process through interactive and student-centered digital media (Solihah et al., 2023).

STEM-based e-LKPD enables the implementation of project-based learning that encourages learners to relate mathematical concepts to authentic situations. Through this medium, students not only understand theory but also learn to apply it in a real context. This framework encourages the development of critical thinking skills, cross-disciplinary problem-solving, and adaptive learning strategies that are urgently needed in solving complex problems (Siller et al., 2024). In addition, using educational technology in STEM approaches has been proven to create an immersive learning environment, increase student engagement, and facilitate collaboration and self-exploration

(Deehan et al., 2024; Lu & Xie, 2024).

The urgent need to improve students' mathematical problem-solving ability in Indonesia is increasingly evident through the results of international assessments such as PISA and TIMSS. The performance of Indonesian students is consistently below the international average, which indicates a gap in the quality of education (Gómez-Talal et al., 2024; X. S. Wang et al., 2023). One of the leading causes is the learning method, which is still dominated by conventional teacher-centered approaches. This approach tends to limit student involvement and inhibit the development of critical thinking and the ability to solve problems independently (Woods & Copur-Gencturk, 2024). In addition, the lack of innovative learning media that can integrate STEM approaches and digital technologies also worsens the situation. This kind of media is crucial in developing students' spatial and mathematical reasoning abilities (Gilligan-Lee et al., 2022).

The development of STEM-based E-LKPD, which is specifically focused on the material of the Pythagorean Theorem, is a strategic effort to answer these challenges. By integrating real-world contexts into learning activities, these media can increase students' active engagement and facilitate reflective and analytical thinking processes. This approach is also in line with the problem-based learning model, which has been proven to improve understanding of 21st-century mathematical concepts and skills such as collaboration and creativity (Chou et al., 2022; Khuda et al., 2024).

Several previous studies have confirmed the effectiveness of STEM approaches in improving student learning outcomes. Bakirci et al. (2022) found that STEM approaches increase students' interest in learning and conceptual understanding. Research conducted by Tonra et al (2022) shows that the use of STEM-based LKPD can improve students' critical thinking and problem-solving ability in secondary mathematics materials. Furthermore, a meta-analysis by Cheng et al. (2022) revealed that integrating computational thinking in STEM learning had a significant positive impact, with an effect size of g = 0.85 on student performance. Interdisciplinary projects combining STEM with the humanities and social sciences fields have also been shown to increase students' self-efficacy in mastering key competencies. However, gender disparities are still found in the perception of these competencies (Fernández-Morante et al., 2022).

However, the existing literature still shows a gap in developing STEM-based E-LKPD, specifically in the Pythagorean Theorem material. Most existing research still uses print-based learning media and has not fully integrated all STEM components in the design of digital LKPD (Lee et al., 2023; Nipyrakis et al., 2025). On the other hand, few studies have used systematic product development methodologies with expert validation and readability tests, even though these methods are essential in ensuring the quality and effectiveness of learning products (Goos et al., 2023).

Based on this background, this study aims to develop a STEM-based E-LKPD on the Pythagorean Theorem material, which is systematically designed by integrating STEM elements and problem-solving activities into one digital device. The novelty of this research lies in the combination of mathematical content and STEM-based interdisciplinary approaches designed through a research and development model that includes expert validation and empirical testing of the readability and applicability of the media. This development model is expected to produce pedagogically and functionally relevant learning products (Kim et al., 2022; Tan et al., 2023).

In particular, the main objective of this study is to develop and evaluate the feasibility and effectiveness of STEM-based E-LKPD in improving students' mathematical problem-solving ability on the Pythagorean Theorem. The products developed are expected to become an alternative to innovative learning media that is easily accessible, supports meaningful learning, and facilitates the achievement of 21st-century competencies.

In terms of scientific contribution, this research enriches the treasure of developing STEM-based learning tools by adding a digital dimension relevant to contemporary learning needs. From a practical perspective, the developed E-LKPD can be an applicative solution for teachers in implementing mathematics learning that is more contextual, interactive, and oriented toward improving students' high-level thinking skills.

METHOD

This development research aims to produce STEM-based E-LKPD on Pythagorean theorem material that meets validity, practicality, and potential effectiveness criteria for enhancing students' problem-solving ability. E-LKPD has proven effective in improving students' learning outcomes and critical thinking abilities (Ulyatin et al., 2023). Integrating the STEM approach in E-LKPD development provides comprehensive learning experiences that enhance students' computational thinking and problem-solving capabilities (Mubharokh et al., 2023).

The study employed the ADDIE development model consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The ADDIE stages were implemented as follows: (1) Analysis: examining teaching material availability, curriculum alignment, and student characteristics to develop contextually relevant E-LKPD; (2) Design: creating material structure, features, and storyboards oriented toward problem-solving indicators; (3) Development: producing the product, expert validation, and small group trials to ensure E-LKPD feasibility and quality (4) Implementation: applying E-LKPD in classroom settings; and (5) Evaluation: assessing overall research objective achievement (Meilisa et al., 2024).

The problem-solving ability indicators are adapted to Polya's model, which has been validated in mathematics education (Felmer, 2023). Polya's model encompasses four stages: understanding the problem, devising a plan, carrying out the plan, and looking back at the solution (L. C. Nguyen et al., 2023). This model helps students overcome mathematical problem-solving difficulties, particularly in geometry and trigonometry contexts relevant to Pythagorean theorem applications (Khofifah et al., 2024). Developing problem-based learning materials through E-LKPD has enhanced students' critical thinking and problem-solving abilities (Chen et al., 2024).

The research involved eighth-grade students from a public junior high school in the 2024/2025 academic year. Small group trials included 6 students (2 groups of 3 students each) to assess practicality, while field implementation involved 30 students to evaluate potential effectiveness. This sampling approach aligns with established E-LKPD development research practices to ensure adequate data collection and validation (Schwarzkopf & Huang, 2024; X. Wang et al., 2024).

Three main instruments were employed: (1) Validation sheets covering content, construction, ICT, and language aspects using a 5-point Likert scale (Very Good=5, Good=4, Fair=3, Less=2, Very Less=1) following established validation procedures for digital learning materials (Meilisa et al., 2024); (2) Practicality questionnaires with 10 statements (7 positive, 3 negative) using a 5-point agreement scale (Strongly Agree=5 to Strongly Disagree=1); and (3) Problem-solving test questions based on four problem-solving indicators that provide comprehensive assessment of student's analytical and reasoning capabilities in STEM contexts (Liu, 2023).

Validation data from expert assessments were analyzed quantitatively by calculating average scores, then interpreted according to validity criteria established by Tobing et al. (2021), as detailed in Table 1. Expert recommendations and suggestions were analyzed qualitatively to inform the product revision process.

Table 1. Validity Criteria

Average score (R)	Information
$4.21 < R \leq 5$	Highly Valid
$3.41 < R \leq 4.21$	Valid
$2.61 < R \leq 3.40$	Quite Valid
$1.81 < R \leq 2.60$	Invalid
$1.00 < R \leq 1.81$	Highly Invalid

Student practicality data were collected through a 10-item questionnaire (7 positive, 3 negative statements) and analyzed by calculating percentage scores. Results were interpreted using Tobing et al. (2021) criteria, as shown in Table 2. Qualitative student feedback was analyzed descriptively for product improvement purposes.

Table 2. Practicality Criteria

Average score (N)	Information
$85 < R \leq 100$	Very Practical
$70 < R \leq 85$	Practical
$55 < R \leq 70$	Quite Practical
$0 < R \leq 55$	Less Practical

Students' suggestions and comments during the trial implementation were analyzed descriptively to inform product revisions. Problem-solving test results were scored using a rubric with the following criteria: blank answers (0 points), incorrect answers (1 point), and correct answers (2 points). Individual scores were calculated using the formula:

$$Score = \frac{obtained\ score}{maximal\ score}\ x\ 100\%$$

Students' problem-solving abilities were then categorized according to the criteria presented in Table 3.

Table 3. Problem-Solving Assessment Criteria

Performance Level	Score Range (%)
Good	$80 < S \leq 100$
Sufficient	$60 < S \leq 80$
Lacking	< 60

The STEM-based E-LKPD demonstrates effectiveness when at least 70% of students achieve 'Good' or 'Sufficient' categories in the post-implementation test. This threshold aligns with educational effectiveness standards, ensuring that learning materials enable most students to reach adequate performance levels.

RESULT AND DISCUSSION

Results

This research focused on developing a STEM-based Electronic Student Worksheet (E-LKPD) for the Pythagorean theorem material. The development process followed the ADDIE instructional design model, which comprises five sequential stages: analysis, design, development, implementation, and evaluation.

1. *Analysis*

Material Analysis

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The material analysis phase involved selecting and examining the Pythagorean theorem as the primary content focus for E-LKPD development. The Pythagorean theorem was strategically chosen as the subject matter because it represents a fundamental geometry concept that requires strong visual representation and demonstrates clear connections to real-world applications. This makes it particularly suitable for grade VIII students following the Merdeka Curriculum framework.

Teaching Material Availability Analysis

Informal interviews conducted with mathematics teachers revealed significant gaps in current instructional approaches. The findings indicated that mathematics instruction continues to rely heavily on conventional teaching methods, primarily utilizing traditional blackboards and static printed worksheets. This conventional approach presents limitations when teaching the Pythagorean theorem, as this mathematical concept requires enhanced visualization tools and interactive elements to facilitate comprehensive student understanding.

2. *Design*

Material Design

The STEM-based E-LKPD was systematically designed to consist of two comprehensive units, each focusing on different aspects of the Pythagorean theorem. The instructional content was carefully adapted from official grade VIII mathematics textbooks published by the Ministry of Education (2017 and 2022), ensuring alignment with curriculum standards. The material design incorporates problem-solving exercises specifically structured to develop students' problem-solving capabilities following Polya's four-step problem-solving framework: understanding the problem, devising a plan, carrying out the plan, and looking back.

Feature Design

The E-LKPD incorporated several interactive technological features to enhance student engagement and learning effectiveness. Key features included carefully selected educational videos from YouTube to provide visual demonstrations and real-world applications of the Pythagorean theorem. The GeoGebra application was also integrated to offer dynamic mathematical visualization and interactive geometric constructions. These multimedia elements were seamlessly embedded within the E-LKPD framework using the Wizer.me platform, which served as the primary hosting and delivery system.

Storyboard Design

A detailed storyboard was developed as the structural blueprint for the E-LKPD development process. The storyboard comprehensively outlined the sequential organization of content elements, including the worksheet title, clearly defined learning objectives, strategically placed educational videos, thought-provoking questions designed to guide student inquiry, and progressive practice problems reinforcing conceptual understanding and skill application.

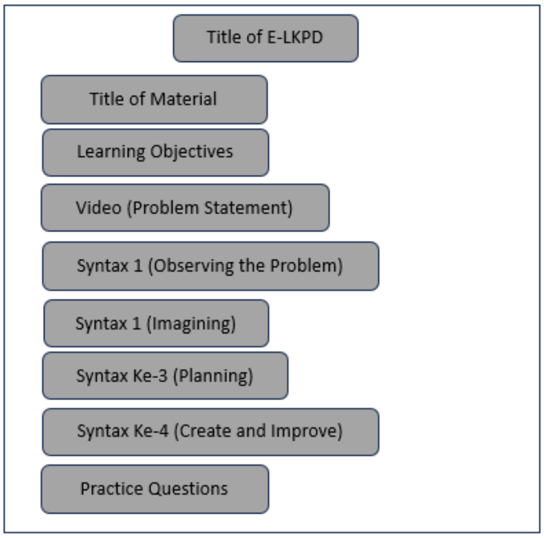


Figure 1. STEM-based E-LKPD Storyboard

3. Development

Expert Validation

The developed E-LKPD underwent a comprehensive validation process conducted by three qualified validators, comprising two subject matter experts and one educational practitioner. The validation assessment was systematically structured around four critical aspects: content validity (appropriateness and accuracy of subject matter), construction validity (structural design and pedagogical framework), Information and Communication Technology (ICT) integration (technological functionality and user interface), and language validity (clarity and appropriateness of linguistic elements). The comprehensive validation results of all validators are systematically presented in Table 4.

Table 4. Expert Validation Results

Assessment Aspect	V1	V2	V3	Average	Criteria
Content	4	4.1	4.3	4.12	Valid
Construction	4.1	4.1	4.3	4.19	Valid
ICT	4.1	4.4	4.5	4.33	Very Valid
Language	4.1	4.1	4.3	4.17	Valid
Overall Average				4.2	Valid

The validation results demonstrate that the developed E-LKPD meets the validity criteria across all assessed aspects. The ICT aspect received the highest validation score (4.33), indicating excellent technology integration and user interface design. All other aspects (content, construction, and language) achieved valid ratings, ranging from 4.12 to 4.19. The average score of 4.20 confirms that the E-LKPD is valid and ready for implementation trials

Small Group Trial

TFollowing the expert validation phase, a small-scale trial was conducted to assess the practicality of the developed E-LKPD. The trial involved six students strategically divided into two collaborative groups of three members each. This small group configuration was chosen to facilitate focused observation of student interactions with the E-LKPD and to gather detailed feedback on usability and effectiveness.

Table 5. Students' Responses During the Trial

No	Students' Responses During the Trial	Follow-Up Actions / Revisions Implemented
1	Students had difficulty understanding the context of the video stimulus "Cat on the Roof" and identifying key information.	Additional guidance was provided to help students recognize the contextual problem related to the Pythagorean Theorem.
2	Students stated that the tower construction	The learning activity was redesigned to be done in

	project was too complex to be completed individually.	small groups to support collaboration and task distribution.
3	Students felt that the number of concept understanding questions was too many to complete within two class periods.	The number of questions was reduced and focused on essential concepts and representative problem-solving items.
4	Students found the questions generally easy but too numerous, which made them feel tired and lose focus.	The questions were redesigned to gradually progress from easy to difficult, and the quantity was adjusted accordingly.
5	Some students had difficulty connecting mathematical concepts to STEM applications, especially in the tower project.	More visual explanations and explicit examples of Pythagorean Theorem applications in the project were added.
6	Students were enthusiastic about using the digital LKPD, but some were not yet familiar with navigating interactive elements.	A usage guide was provided at the beginning of the lesson, including a demonstration of interactive features.
7	Students appreciated the real-world context, but needed more time for in-depth exploration and understanding.	Additional time was allocated for exploration and discussion, and scaffolding was provided to support student thinking.

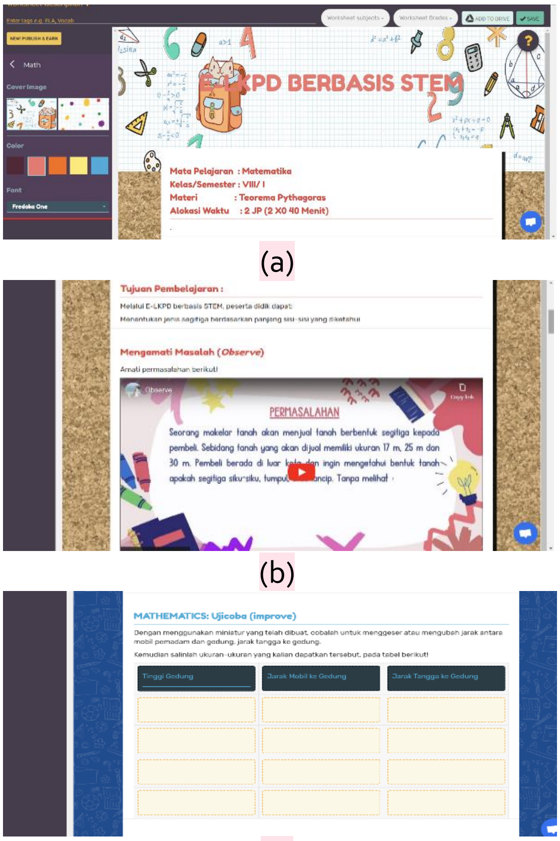
Following the trial activities, students completed a comprehensive practical questionnaire to evaluate multiple aspects of the E-LKPD's functionality and user experience. The detailed results of this assessment are systematically presented in Table 5.

Table 6. Practicality Questionnaire Results

Student	Percentage (%)	Description
S1	88	Very Practical
S2	86	Very Practical
S3	80	Practical
S4	82	Practical
S5	90	Very Practical
S6	86	Very Practical
Average	85.33	Very Practical

The practical assessment results indicate highly positive student responses to the E-LKPD implementation. Four out of six students (67%) rated the E-LKPD as "Very Practical," with scores ranging from 86% to 90%, while the remaining two students rated it as "Practical," with scores of 80% and 82%. The overall average score of 85.33% falls within the "Very Practical" category, demonstrating that students found the E-LKPD easy to use, engaging, and beneficial for their learning process. This high practicality score suggests that the E-LKPD is well-designed for student interaction and ready for broader implementation

The high practicality scores are reflected in the user-friendly design of the E-LKPD, as illustrated in Figure 2



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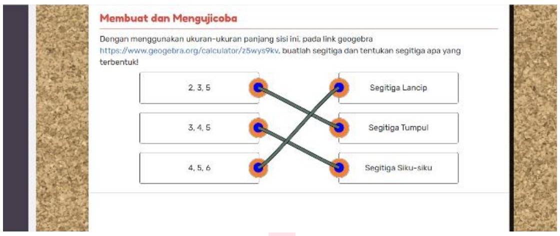

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Figure 2. Results of STEM-based E-LKPD Development

4. *Implementation Stage*

Meeting 1

The first implementation session began with a comprehensive orientation, during which students received detailed instructions on creating accounts and operating the STEM-based E-LKPD through the Wizer.me application platform. Students then engaged with the first E-LKPD unit, which followed the STEM syntax structure, beginning with observation activities.

During the observation phase, students observed selected YouTube videos that illustrated real-world mathematical applications. The featured video depicted firefighters conducting evacuation procedures using ladders, demonstrating how ladder positioning must be determined safely and effectively to reach building rooftops. This video effectively illustrated how the building height, the distance from the ladder base to the wall, and the ladder length form a proper triangle configuration.

Following the observation phase, students engaged in creative visualization activities by creating drawings illustrating the video scenarios on provided digital canvases. This imaginative exercise encouraged creative thinking in understanding situations and presenting ideas, helping students identify problems while connecting mathematical concepts to real-world contexts and enhancing creativity and imagination.

The next phase involved logical analysis, where students examined their illustrations to identify mathematical relationships, such as determining hypotenuse and height measurements. Subsequently, students proceeded to hands-on experimentation by planning and testing mockups/miniatures created in previous stages. They manipulated the dimensions of their miniatures until they could observe sides forming right triangles, training them to explore various possible scenarios systematically.

The session concluded with practice exercises, during which students could respond using three alternative methods: direct text input, uploading photographs of handwritten solutions, or utilizing voice recording features to explain their answers verbally.

This activity trains students to try some possible cases. Figure 3 shows a snippet of students' answers to this miniature trial.

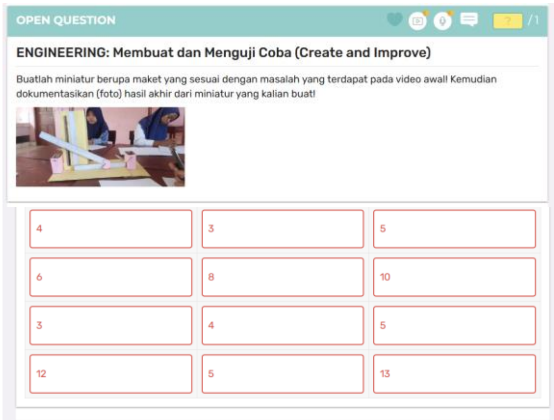


Figure 3. Students' Responses to Miniature Trials

Meeting 2

The second implementation session presented students with a STEM-based E-LKPD centered around the fundamental question: "Is the land shape a right triangle, obtuse triangle, or acute triangle?" Students began by watching introductory videos, then utilized mockups/miniatures from the previous meeting to visualize land configurations and describe geometric shapes using the GeoGebra application.

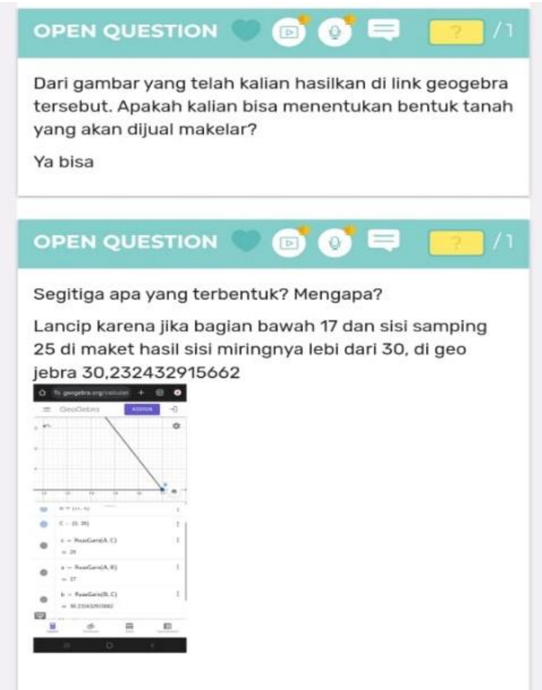


Figure 4. The Results of Students' Answers Regarding the Shape of the Soil Obtained

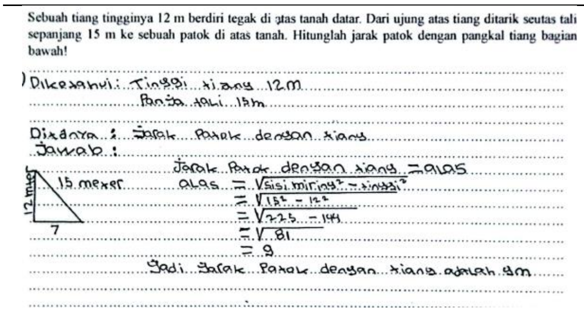
This comprehensive activity sequence encouraged students to systematically observe video content, organize relevant information, plan solutions by understanding land dimensions, select appropriate problem-solving steps using Pythagorean theorem principles for value comparison, and draw logical conclusions about land shapes based on their calculated results. Students successfully demonstrated their ability to determine land shapes by systematically applying geometric principles and theorem-based analysis.

Upon completing both implementation sessions, students participated in comprehensive testing to assess the potential effects of the developed STEM-based E-LKPD on their problem-solving ability development.

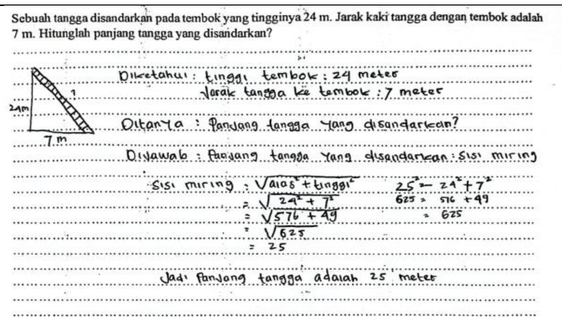
5. *Evaluation*

Problem Solving Ability Test

After participating in learning using STEM-based E-LKPD, students were given a problem-solving ability test consisting of 5 questions. The students' answers during the problem-solving ability test can be seen in Figure 5.



(a)



(b)

Problem (translated):
A pole with a height of 12 m stands vertically on flat ground. From the top of the pole, a rope 15 m long is stretched to a stake on the ground. Calculate the distance from the stake to the base of the pole.
Student's Answer (translated):
Given:

- Height of the pole = 12 m
- Length of the rope = 15 m

Solution:
Distance from the stake to the base of the pole:
Let's denote:

Problem (translated):
A ladder is leaning against a wall that is 24 meters high. The distance from the foot of the ladder to the wall is 7 meters. Calculate the length of the ladder.
Student's Answer (translated):
Given:

- Height of the wall = 24 meters
- Distance from the foot of the ladder to the wall = 7 meters

Question:
What is the length of the ladder?

• Hypotenuse = length of the rope = 15 • Height = 12 • Base = distance from stake to base of the pole Using the Pythagorean theorem: Base = $\sqrt{hypotenusa^2 - heigt^2}$ = $\sqrt{15^2 - 12^2}$ = $\sqrt{225^2 - 144^2}$ = $\sqrt{81}$ = 9 **So, the distance from the stake to the base of the pole is 9** meters.	Solution: The length of the ladder is the hypotenuse. Using the Pythagorean theorem: Hypotenuse = $\sqrt{height + base^2}$ = $\sqrt{24^2 + 7^2}$ = $\sqrt{576 + 49}$ = $\sqrt{625}$ = 25 So, the length of the ladder is 25 meters.

Figure 5. Students' Answers of Problem-Solving Ability Test

Figure 5 presents examples of two students' responses to the problem-solving ability test questions. The analysis of both responses demonstrates different competency levels across the four problem-solving stages. Student A, as shown in Figure 6(a), exhibits good problem comprehension skills by accurately identifying and writing down the known information, specifically pole height = 12 meters and rope length = 15 meters, while clearly stating that the question asks for the distance from the stake to the base of the pole. In the planning stage, Student A demonstrates appropriate strategic thinking by selecting the Pythagorean theorem as the solution approach, which is correct since the problem involves right triangles. During the implementation phase, Student A systematically executes the planned approach by writing the formula to find the distance between the stake and the pole base, followed by methodical calculation steps that yield the correct answer of 9 meters. However, in the verification stage, Student A does not check the answer or review the solution steps, though the final answer is correct, indicating solid concept mastery despite the incomplete problem-solving process.

Student B, illustrated in Figure 6(b), demonstrates more comprehensive problem-solving abilities across all four stages. In understanding the problem, Student B creates a clear sketch and accurately records all known information, including wall height = 24 meters and distance from the ladder base to the wall = 7 meters, while explicitly stating what the question requires. The planning stage shows Student B's ability to apply the appropriate strategy by correctly identifying the need to use the Pythagorean theorem for this right triangle problem. During implementation, Student B executes the plan by writing the formula to find the ladder length (hypotenuse) and performing accurate calculations, arriving at the correct answer of 25 meters. Most notably, in the verification stage, Student B demonstrates excellent checking habits by substituting the result c = 25 back into the Pythagorean theorem formula to verify the answer's accuracy, concluding with a clear statement that the ladder length is 25 meters.

The comparative analysis reveals that both students possess good problem-solving abilities. Student B shows more comprehensive skills by completing all four problem-solving stages, including the crucial verification step. These results indicate that the developed STEM-based E-LKPD effectively enhances students' problem-solving capabilities in Pythagorean theorem applications. After completing the problem-solving ability test, a comprehensive analysis was conducted based on the problem-solving indicator assessment rubric, with the overall results presented in Figure 6.

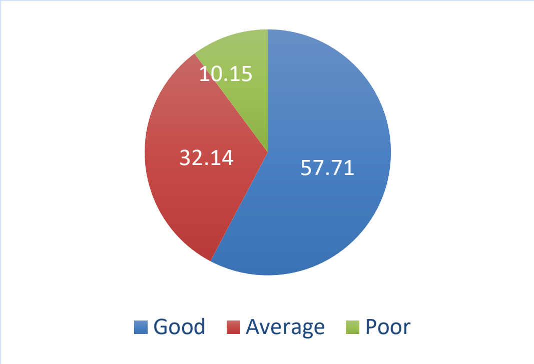


Figure 6. Problem-Solving Ability Test Results

Based on Figure 6, the student's problem-solving ability test results are in the good category, with details of 10.15% of students in the poor category, 32.14% sufficient, and 57.71% others good. So, the STEM-based E-LKPD in the Pythagorean theorem material developed has a potential effect on students' problem-solving ability and can be used in learning.

Formative Evaluation

The formative evaluation in this study refers to the previous stages. At these stages, suggestions and useful responses were received to improve the E-LKPD. In addition, assessments were carried out by experts and students. Table 6 summarizes the results of the formative evaluation for the developed E-LKPD.

Table 7. Recapitulation of the Evaluation of E-LKPD Development

Aspects	Result	Information
Validity	Based on expert assessments, the overall average validity is 4.20, which means that the E-LKPD on the Pythagorean theorem material developed is valid in terms of content, construction, ICT, and language.	Valid
Practicality	The results of the practicality questionnaire given to students during the small group trial showed that the percentage of practicality of the E-LKPD developed reached 85.33%.	Very Practical
Potential Effects	The problem-solving ability test conducted after learning using STEM-based E-LKPD showed that most of the students' problem-solving ability were in the good category.	Has a potential effect

Discussion

Validity of STEM-Based E-LKPD

The validation results indicate that the STEM-based E-LKPD on the Pythagorean Theorem material achieved an overall average score of 4.20, which is categorized as valid. This score reflects a comprehensive expert evaluation covering four critical aspects: content, construction, ICT integration, and language. These findings confirm that the E-LKPD is ready for implementation in classroom settings.

Among these aspects, the ICT integration received the highest average score of 4.33. This indicates that integrating digital features and the quality of user interface design are of excellent standard. Using platforms such as GeoGebra and Wizer.me aligns with current best practices in digital learning environments. This finding is supported by Toma et al. (2023), who emphasized the role of ICT in enhancing engagement and understanding during mathematics instruction. Similarly, Butcher (2024) explained how technology-supported learning environments significantly improve students' comprehension and interaction with content when grounded in strong theoretical frameworks.

The content validity score of 4.12 shows that the material is well-aligned with the Merdeka Curriculum and structured logically. Given the documented challenges in mastering the Pythagorean Theorem, this alignment is crucial for Grade VIII students. Due (2024) pointed out that structured learning support is essential to make abstract mathematical concepts more accessible. Furthermore Mukuka et al. (2022) found that interactive digital worksheets enhance students' mathematical reasoning, particularly in geometry topics such as the Pythagorean Theorem.

The construction aspect obtained a score of 4.19. This indicates that the E-LKPD is well-designed both structurally and pedagogically. Its layout follows Polya's four-step problem-solving process, which includes understanding the problem, devising a plan, executing it, and evaluating the solution. Amalina and Vidákovich (2023) highlighted that applying structured problem-solving models like Polya's promotes the development of higher-order thinking skills among students.

The language aspect achieved an average score of 4.17. This shows that the instructional language used is appropriate for students and effectively supports their understanding of mathematical concepts. Clarity of language is especially critical in STEM learning, where complex ideas must be communicated easily. Eviliasani et al. (2022) demonstrated that explicit language, supported by visual and interactive tools such as GeoGebra, significantly improves students' conceptual understanding.

The expert validation results indicate that the STEM-based E-LKPD is valid across all key aspects. Integrating pedagogical structure, curriculum relevance, technological features, and effective communication makes this E-LKPD a promising tool to support students' mathematical reasoning and problem-solving development in the Pythagorean Theorem topic.

Practicality and User Experience

The practicality test of the STEM-based E-LKPD yielded a percentage score of 85.33%, which is categorized as very practical. This result indicates that the E-LKPD was perceived by students as easy to use, engaging, and helpful in supporting their learning process. The high practicality score was supported by integrating multimedia elements such as instructional videos, voice recordings, and dynamic GeoGebra visualizations, which enhanced students' understanding of Pythagorean Theorem concepts.

This finding aligns with the study by Gumbi et al. (2024), who emphasized that the effective use of digital tools in STEM learning can foster motivation and engagement when platforms are tailored to student needs. Similarly, Al Shamsi (2024) highlighted that e-learning platforms with multimedia and interactive features significantly improve learning outcomes in STEM subjects. Using Wizer.me as a delivery platform allowed accessible, user-friendly learning experiences that accommodated diverse learner preferences.

Using GeoGebra in the E-LKPD provided dynamic visualizations that played an essential role in helping students explore and manipulate geometric relationships. According to Türkoğlu and Yalcinalp (2024), integrating GeoGebra in geometry learning environments enhances students' spatial reasoning and supports deeper conceptual understanding by enabling interactive exploration.

Results from the small group trial involving six students further confirmed the practicality of the learning media. Four students rated the E-LKPD as very practical, with scores between 86% and 90%, while the remaining two rated it as practical, with scores of 80% and 82%. These responses indicate that the E-LKPD was well received by the target users and functioned effectively during the trial.

Moreover, students appreciated the

flexibility offered by the platform, which allowed them to submit responses through various modes such as typing, uploading photos of written work, or recording voice explanations. This flexibility supported different learner needs and promoted inclusivity. As stated by Gençer et al. (2023), selecting digital tools based on pedagogical relevance and ease of use is crucial in online learning environments, and this principle was evident in the design of the E-LKPD.

7

Impact on Problem-Solving Abilities

The results of the problem-solving ability test showed a positive impact after the implementation of the STEM-based E-LKPD. A total of 57.71% of students achieved scores within the "Good" category, 32.14% were in the "Sufficient" category, and only 10.15% fell into the "Poor" category. These findings demonstrate the potential effectiveness of the E-LKPD in improving students' mathematical problem-solving ability, particularly in applying the Pythagorean theorem.

The improvement can be attributed to the contextual learning experience provided by integrating STEM elements. Analyzing firefighter evacuation scenarios and determining land shapes allowed students to relate mathematical concepts to real-life situations. These activities supported all four stages of Polya's problem-solving framework. According to Aba-Oli et al. (2024), STEM-based problem-based learning can effectively promote higher-order thinking when tasks are grounded in real-world contexts and encourage students to engage in inquiry and reflection.

The use of GeoGebra helped students visualize geometric models and manipulate mathematical representations. Türkoğlu and Yalcinalp (2024) highlighted that integrating digital visualization tools such as GeoGebra facilitates students' spatial reasoning and enhances procedural fluency in geometry. Additionally, including multimedia content in the E-LKPD created an engaging learning atmosphere that nurtured deeper understanding. This aligns with the findings of Lu and Xie (2024), who concluded that educational technology significantly enhances students' problem-solving abilities when it supports exploration and interactive learning processes.

The multidisciplinary nature of the E-LKPD, involving elements such as design, engineering, and digital tools, provided opportunities for students to apply analytical and creative thinking. Students were encouraged to draw diagrams, design simple models, and interact with simulations. According to Goos et al. (2023), interdisciplinary STEM approaches can cultivate critical mathematical thinking when learners are exposed to tasks that connect mathematics with broader contexts.

Furthermore, the structured scaffolding embedded in the E-LKPD supported the development of systematic and reflective thinking habits. As Solihah et al. (2023) pointed out, STEM-based educational designs that emphasize sustainability and step-by-step inquiry encourage students to test, evaluate, and revise their approaches to solving complex problems. Complementarily, Topsakal et al. (2022) reported that problem-based STEM activities enhance students' confidence and perception of their critical thinking and problem-solving capabilities.

The Role of STEM E-LKPD in Enhancing Students' Problem-Solving Ability

The STEM-based E-LKPD significantly improves students' problem-solving abilities by integrating real-world contexts, interactive technologies, and structured learning strategies. Each component of STEM contributes specifically to this development. Science supports inquiry and conceptual understanding, technology provides tools for visualization and experimentation, engineering fosters systematic design and evaluation, and mathematics strengthens logical reasoning and analytical processes (English, 2023; Goos et al., 2023).

The learning activities in the E-LKPD were structured using Polya's four-step problem-solving model: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. STEM-based learning components supported each stage. For instance, the firefighter ladder scenario required students to analyze a practical situation, use digital tools such as GeoGebra, apply geometric reasoning, and evaluate their conclusions. This reflects the findings of Tan et al. (2023), who emphasized the effectiveness of STEM problem-solving through inquiry and reasoning cycles in meaningful contexts.

Technology provided real-time feedback and supported students in revising their strategies, which is crucial for developing metacognitive and adaptive skills. This aligns with the findings of Lu and Xie (2024), who concluded that educational technology enhances learning by enabling students to self-monitor and refine their problem-solving approaches. Collaborative activities within the E-LKPD also strengthened students' communication and critical thinking, in line with the work of Felmer (2023), who noted that collaborative problem-solving in mathematics fosters cognitive flexibility and deeper understanding.

Moreover, integrating context-rich tasks enabled students to transfer mathematical knowledge to new situations, improving their ability to generalize and adapt strategies. Topsakal et al. (2022) showed that problem-based STEM education significantly influences students' critical thinking and perceptions of problem-solving ability, while Nurita et al.(2024) highlighted how STEM tasks enhance creativity through interdisciplinary exploration.

Implication of Research

The successful development and implementation of the STEM-based E-LKPD provide several important implications for mathematics education, particularly in enhancing students' problem-solving abilities. Integrating real-world contexts, such as video-based scenarios and practical problem representations, helped students connect abstract mathematical concepts to everyday applications. According to Deehan et al. (2024), STEM integration in classrooms supports contextualizing mathematical ideas, creating more meaningful and authentic learning environments that align with students' real-life experiences.

Using platforms like Wizer.me enabled flexible instructional design, allowing educators to tailor materials using multimedia, open-ended prompts, and various response formats. This aligns with the findings of Gencer et al. (2023), who showed that digital learning environments utilizing Web 2.0 tools can cater to diverse learning preferences and promote conceptual understanding in science and mathematics through interactive design features.

Furthermore, the E-LKPD promoted active learning through observation, model construction, creative representation, experimentation, and reflective dialogue. These strategies align with emphasizing higher-order thinking and inquiry-oriented learning in STEM education. Fang et al. (2023) emphasized that self-regulated, interactive learning in STEM

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3 settings supports academic achievement and metacognitive development.

Integrating GeoGebra in the E-LKPD enhanced students' spatial reasoning and understanding of geometry concepts, such as triangle classification and the Pythagorean theorem. Türkoğlu and Yalçınalp (2024) found that digital tools like GeoGebra help learners visualize dynamic geometric relationships and improve problem-solving strategies through interactive manipulation of mathematical objects.

Additionally, the digital nature of the E-LKPD improved instructional efficiency. Teachers could monitor student progress in real time and provide immediate feedback, enhancing responsiveness and personalization. Triplett (2023) supports this, noting that technology-integrated STEM education increases engagement and learning outcomes, particularly when the digital tools are pedagogically aligned.

Platforms like Google Classroom and Wizer.me supported formative assessment while reducing teachers' administrative burden. According to Nguyen et al. (2024), integrating ICT tools in STEM learning environments fosters student autonomy, streamlines instruction, and facilitates continuous assessment and feedback loo.

Limitation

Although this study yielded promising results in developing and implementing a STEM-based E-LKPD, several limitations must be acknowledged. The first limitation relates to the small sample size of only 30 students. While this number was sufficient for initial development and limited field testing, it reduces the generalizability of the findings to broader populations. Moreover, the limited implementation period, which involved only two
3 learning sessions, might not fully capture long-term learning gains or the durability of students' problem-solving ability. A more extended application across several topics would provide deeper insights into the sustained effects of the E-LKPD.

Another limitation lies in using a single-group design without a control group. This approach restricts the ability to make strong causal claims because the improvements observed in students' performance may not be solely attributed to using the STEM-based E-LKPD. Future research should incorporate more rigorous methodologies, such as quasi-experimental or experimental designs, to strengthen internal validity. Additionally, the content focus was limited to the Pythagorean theorem. Although this topic is appropriate for STEM integration, further investigation is needed to determine whether similar digital worksheets are effective in other mathematical areas such as algebra, number theory, or statistics.

Lastly, the analysis in this study was based on descriptive statistics alone. While the results suggest a positive impact, the lack of inferential statistical analysis, such as t-tests or ANOVA, prevents the drawing of conclusions regarding the statistical significance of the findings. Future studies should integrate inferential methods to produce stronger empirical evidence. Considering these limitations, the current validation of the STEM-based E-LKPD is preliminary. Further research involving larger and more diverse samples, extended durations, and stronger research designs is essential to confirm and expand upon these findings.

CONCLUSION

This study aimed to develop and evaluate a STEM-based Electronic Student Worksheet (E-LKPD) focused on Pythagorean theorem material to enhance students'

2

problem-solving abilities. The development followed the ADDIE model and was validated through expert assessment, small group trials, and field implementation. The results showed that the E-LKPD met the validity criteria with an overall average score of 4.20, particularly excelling in ICT (4.33). The practicality assessment yielded a high score of 85.33%, indicating that students found the digital worksheet accessible and beneficial. Furthermore, the effectiveness test revealed that 57.71% of students reached the "Good" category, demonstrating a positive potential impact of the E-LKPD on students' problem-solving ability. These findings confirm that the developed product is valid, practical, and potentially effective for mathematics learning aligned with the Merdeka Curriculum.

Future research is recommended to expand the scale and duration of implementation, include control groups for stronger comparisons, and apply the E-LKPD model to other mathematical topics beyond the Pythagorean theorem. Longitudinal studies help evaluate the sustainability of learning gains, while inferential statistical analysis offers more rigorous evidence of impact. From a practical standpoint, mathematics teachers are encouraged to adopt STEM-based digital worksheets to foster student engagement, facilitate contextual learning, and support the development of higher-order thinking skills in line with 21st-century competencies. Educational policymakers may also consider integrating similar tools within national learning platforms to promote innovation and effectiveness in digital mathematics instruction.

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