

## Developing STEM-Based Digital Worksheet to Encourage Students' Problem-Solving Skills

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### ABSTRACT

Mathematics education in the 21st century, a field increasingly shaped by rapid technological advancement and global demands for critical thinking, necessitates the use of contextual, technology-enhanced learning media that promote higher-order thinking skills, particularly in the area of problem solving. Addressing this need, the present study focused on developing a STEM-based digital worksheet, a technology-integrated instructional tool aimed at enhancing students' mathematical problem-solving skills within the topic of the Pythagorean Theorem. Adopting a Research and Development (R&D) framework, specifically the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), the study involved a series of methodical phases designed to ensure both pedagogical soundness and technological relevance. Data collection involved conducting interviews and observations, analyzing relevant documents, validating content through expert review, and administering both practicality questionnaires and performance-based assessments grounded in Polya's problem-solving rubric. Validation by three subject-matter experts, serving as evaluators of content quality and instructional alignment, resulted in an average score of 83.68%, denoting high validity. Practicality, assessed through one-on-one and small-group trials, achieved a mean score of 82.33%, reflecting strong user acceptance and ease of implementation. A field test with 30 students revealed an average problem-solving score of 75%, with notable strengths in identifying and understanding the problem, and relative weaknesses in the final stage of reviewing solutions. These findings, while preliminary, suggest that developing and implementing STEM-based digital worksheets can serve as a promising approach to fostering mathematical problem solving by embedding learning in contextual, interactive, and technologically enriched environments.

**Keyword** : STEM-based digital worksheet, problem-solving skills

### ABSTRAK

Pembelajaran matematika abad ke-21 menuntut media yang kontekstual, berbasis teknologi, dan mampu mengembangkan keterampilan berpikir tingkat tinggi, khususnya kemampuan pemecahan masalah. Penelitian ini bertujuan mengembangkan lembar kerja digital berbasis STEM yang valid, praktis, dan berpotensi efektif untuk meningkatkan kemampuan pemecahan masalah matematis siswa pada materi Teorema Pythagoras. Metode penelitian yang digunakan adalah Research and Development (R&D) dengan model pengembangan ADDIE, yang meliputi tahapan analisis, desain, pengembangan, implementasi, dan evaluasi. Pengumpulan data dilakukan melalui wawancara, observasi, analisis dokumen, validasi ahli, angket kepraktisan, dan penilaian kinerja siswa menggunakan rubrik Polya. Hasil validasi oleh tiga ahli menunjukkan tingkat validitas sebesar 83,68%, sementara uji kepraktisan melalui one-to-one dan small group menghasilkan skor kepraktisan sebesar 82,33%. Uji

lapangan terhadap 30 siswa menunjukkan rata-rata skor kemampuan pemecahan masalah sebesar 75%, dengan indikator “memahami masalah” memperoleh skor tertinggi dan “meninjau solusi” skor terendah. Temuan ini menunjukkan bahwa E-LKPD berbasis STEM yang dikembangkan tergolong valid, praktis, dan memiliki potensi efektivitas dalam mendukung pengembangan kemampuan pemecahan masalah siswa melalui aktivitas pembelajaran yang kontekstual, interaktif, dan terintegrasi dengan teknologi.

**Kata Kunci** : E-LKPD berbasis STEM, kemampuan pemecahan masalah

## INTRODUCTION

Problem-solving has become a fundamental competency that all students must develop in the 21st century. Education today is not limited to transmitting knowledge. Still, it aims to foster higher-order thinking skills such as critical thinking, creativity, adaptability, and responding to complex real-world challenges in a digital society (Xu & Zhou, 2022). Mathematics plays a central role in achieving this goal. According to the National Council of Teachers of Mathematics (NCTM), mathematics education should prioritize problem-solving, reasoning, communication, and connecting as core learning processes (Angraini & Fitri, 2023).

Problem-solving is a structured cognitive process that includes identifying a problem, formulating and implementing a strategy, and evaluating the solution. This process requires a combination of logical reasoning, creative thinking, and metacognitive awareness (Munzar et al., 2021). However, results from international assessments such as the Programme for International Student Assessment (PISA) consistently show that Indonesian students perform below the OECD average in mathematical problem-solving, revealing significant gaps in instructional practice and student competencies (Setiawan et al., 2023). This underperformance highlights the need to enhance pedagogical approaches that support meaningful, student-centered, and inquiry-based mathematical learning (Tellerino, 2024).

To respond to this challenge, various pedagogical models have been introduced, including Problem-Based Learning (PBL), Realistic Mathematics Education (RME), Creative Problem Solving (CPS), Problem Posing, and Discovery Learning. These approaches have positively impacted students' understanding and engagement in mathematics (Roble et al., 2021). Despite their potential, many of these models still rely heavily on conventional or paper-based learning resources, limiting their interactivity and adaptability in technology-rich learning environments (Khalid et al., 2020).

As technology integration in education becomes increasingly important, digital learning tools offer promising opportunities to support active and flexible learning. One such tool is the electronic student worksheet, which can provide multimedia-rich, interactive, and accessible learning experiences that promote learner autonomy and engagement (Fattikasari & Nasrudin, 2023). When carefully designed, digital worksheets can include features such as simulations, animations, embedded assessments, and guided inquiries that support critical and creative thinking in mathematics (Wulandari & Andriyani, 2022). However, research specifically targeting digital worksheets to improve students' mathematical problem-solving abilities remains limited, especially at the junior high level.

One instructional approach that aligns well with 21st-century learning objectives is STEM (Science, Technology, Engineering, and Mathematics). STEM education offers a contextual and interdisciplinary framework that enables students to apply mathematical concepts to real-world problems through scientific inquiry, engineering design, and the use of technology (Djoeaeriah & Iskandar, 2024). Integrating STEM into digital learning materials has increased students' motivation, enhanced their problem-solving and critical thinking skills, and fostered deeper conceptual understanding (Zainil et al., 2022). Nonetheless, a few studies have explicitly developed and validated digital worksheets that integrate STEM principles with a focus on improving mathematical problem-solving (Hairunnisa et al., 2022; Wulanningtyas & Ratnasari, 2022)

This study aims to fill that gap by developing and validating a STEM-based electronic student worksheet on the Pythagorean Theorem, tailored to junior high school students. The digital worksheet uses the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), integrating multimedia content and contextualized STEM tasks that engage students in problem-based learning environments. By combining STEM-oriented inquiry with digital interactivity, the worksheet is expected to enhance students' mathematical problem-solving skills in a structured, relevant, and student-centered manner.

The significance of this research lies in its contribution to theoretical and practical domains. It offers a model for integrating STEM pedagogy and digital innovation into mathematics instruction while providing a validated learning resource that aligns with curriculum standards and 21st-century education demands. By developing this STEM-based digital worksheet, the study aims to support the implementation of technology-enhanced learning environments that foster student engagement, improve problem-solving performance, and prepare learners for future academic and professional challenges.

## **METHOD**

This study employed a Research and Development (R&D) design using the ADDIE model, which consists of five sequential phases: Analysis, Design, Development, Implementation, and Evaluation. The goal was to develop a valid, practical, and potentially effective STEM-based electronic student worksheet (E-LKPD) to enhance students' mathematical problem-solving skills on the Pythagorean Theorem. The ADDIE model was selected due to its structured yet adaptable framework, which allows iterative refinement of learning materials based on empirical findings and pedagogical objectives (Adeoye et al., 2024).

The research began with a comprehensive needs assessment involving a Grade VIII mathematics teacher, thirty students, and curriculum documents. Data were collected through interviews, surveys, and analysis of the Independent Curriculum's Phase D learning outcomes. This phase identified the students' cognitive characteristics, learning preferences, and access to technology, along with existing challenges in classroom instruction (Utami et al., 2024). The analysis results informed the design of the E-LKPD, which incorporated STEM-oriented features such as contextual video prompts, illustrative images, and project-based problem scenarios. These features were aligned with Polya's four-stage problem-solving model to support the development of higher-order mathematical reasoning (Arifin et al., 2021). In addition to content design, several evaluation instruments were developed, including

expert validation rubrics, practicality questionnaires, and performance assessment rubrics (Hartini et al., 2020).

The initial prototype was developed using the Wizer.me platform, which supports the integration of multimedia and interactive components. To assess its validity, the digital worksheet was reviewed by three mathematics education experts who evaluated the content based on four aspects: conceptual accuracy, language clarity, visual-technical design, and technological integration. A four-point Likert scale and descriptive percentage analysis were used to quantify expert feedback, with a minimum threshold of 75% set to indicate acceptable validity (Fahlevi et al., 2022).

Following expert review and revision, the prototype was implemented through one-on-one and small-group trials to examine its practicality. The one-on-one session involved three students with different cognitive abilities and one teacher, focusing on clarity of instructions, interface usability, and content comprehensibility. Revisions from this phase were tested in a small-group setting with six students representing diverse learning styles. A 14-item practicality questionnaire using a five-point Likert scale was distributed, with at least 75% positive responses as the benchmark for acceptable practicality (Wahyuni et al., 2021). These early-stage trials were not designed to evaluate learning outcomes but to inform usability and interface improvements.

The final evaluation of the worksheet's potential effectiveness was conducted during a large-scale classroom implementation involving 30 students. In this stage, students completed contextual problem-solving tasks related to the Pythagorean Theorem. Their performance was assessed using a rubric adapted from Polya's framework, encompassing the stages of understanding the problem, devising a plan, executing it, and reviewing the solution. Quantitative data were analyzed through descriptive statistics based on mean scores for each problem-solving indicator. Meanwhile, qualitative data from students' responses and written explanations were analyzed using thematic categorization to identify strategy patterns and representational reasoning (Khairuna, 2023).

The participants in this study included three expert validators, one Grade VIII mathematics teacher, and thirty students from SMP Negeri 4 Lubai Ulu, selected through purposive sampling to represent a variety of learning profiles. Data collection techniques comprised interviews, document analysis, classroom observations, questionnaires, and student task performance evaluations. Quantitative data were processed descriptively, while qualitative data were examined through thematic reduction and interpretive synthesis to evaluate the educational value, usability, and potential learning impact of the developed digital worksheet.

## **RESULTS AND DISCUSSION**

### **Description of STEM-based Digital Worksheets**

One of this research's objectives is to produce a valid and practical STEM-based digital worksheet that can be used to train junior high school students' problem-solving skills. The applications used to develop STEM-based digital worksheets are Wizer.me. The material used is the Pythagoras Theorem. This research's stages align with the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation.

## **1. Analysis Stage**

### **a. Analysis of Characteristics and Needs of Students**

Student characteristics were analyzed using secondary data obtained from the mathematics teacher of Grade VIII at SMP Negeri 4 Lubai Ulu. These data were derived from a non-cognitive initial assessment previously administered by the teacher. The identified characteristics included students' learning styles, thinking habits, and cognitive levels.

In addition to document analysis, the researcher interviewed the mathematics teacher of Grade VIII to gain further insights into the classroom learning process. The interview explored the use of learning models, instructional resources, and media employed during mathematics instruction. The interview findings concluded that the teacher rarely integrated ICT into mathematics teaching and had never used digital worksheets or STEM-based learning approaches. ICT was limited to basic tools such as PowerPoint presentations and occasional use of applications like Kahoot for quizzes or assessments. The primary reasons for limited ICT use included students' lack of internet data packages and unstable electricity, which often affected signal availability.

### **b. Curriculum and Material Analysis**

SMP Negeri 4 Lubai Ulu implements the Independent Curriculum (Kurikulum Merdeka). According to this curriculum, the Pythagorean Theorem is one of the topics covered in the odd semester for Grade VIII students. This topic is appropriate for developing students' problem-solving skills due to its conceptual depth and applicability to real-world contexts.

Therefore, the Pythagorean Theorem was selected as the focus material for developing the STEM-based digital worksheets in this study. The instructional tool was subsequently tested on Grade VIII students at SMP Negeri 4 Lubai Ulu to examine its effectiveness in supporting problem-solving-oriented learning.

## **2. Design Stage**

The second stage in the ADDIE development model is the design stage. In this phase, the researcher developed a STEM-based digital worksheet focused on the Pythagorean Theorem and structured for two learning sessions. The design process emphasized the integration of the four STEM components: Science, Technology, Engineering, and Mathematics. To ensure this integration, the researcher planned the instructional content, selected interactive features, and created a storyboard that mapped each activity to specific learning objectives and STEM aspects. The products of this stage consist of three elements: the instructional material design, the selection of digital features, and the development of a storyboard using the wizer.me platform.

### **a. Material Design**

The instructional content in the STEM-based digital worksheet was adapted from several educational references, including the Grade VIII mathematics textbook published by the Ministry of Education and Culture (2022). The Material on the Pythagorean Theorem was designed using contextual and inquiry-based questions. These questions were intended to introduce real-life problems related to measurement and geometry, build conceptual understanding, and enhance students' ability to apply the Pythagorean Theorem to solve problems. This content supports developing scientific reasoning and mathematical skills in a meaningful context.

### **b. Feature Selection**

To promote interactive learning, various digital features were incorporated through the Wizer.Me platform. These features included videos, images, audio elements, and tables. One of the video features was used to guide students in designing a simple tower model using right-angle triangles. This activity aimed to foster technological awareness and basic engineering practices by engaging students in a real-world problem-solving project. The other multimedia elements were selected to support diverse learning preferences and improve students' conceptual understanding through visual and auditory stimulation.

**c. Storyboard Design**

The instructional content and selected features were organized into a detailed storyboard. This storyboard outlined the sequence of learning activities, the placement of digital elements, and the alignment with STEM learning goals. Table 1 served as a visual guide for implementing the digital worksheet and ensured that each learning phase was consistent with the intended outcomes.


**Table 1.** Alignment of STEM components and learning activities

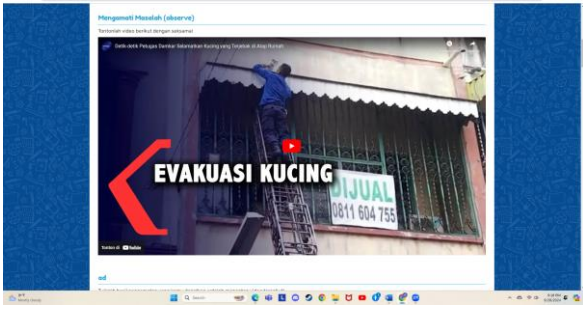
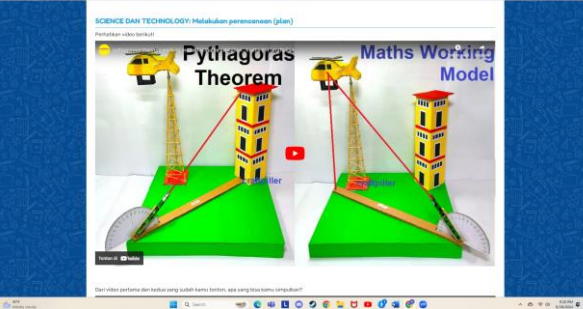
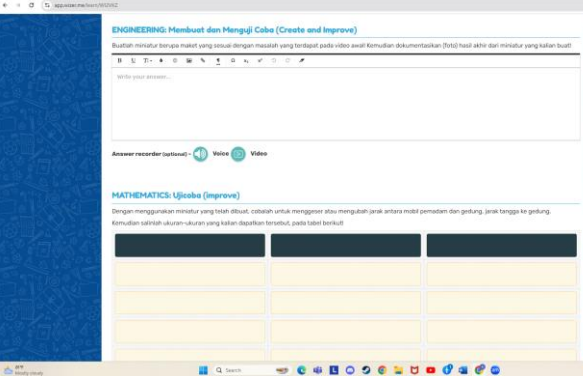
STEM Component	Description of Learning Activities	Implementation in Digital Worksheet
Science	Exploring real-world phenomena involving measurement and observation	Contextual questions related to distance and height using right-angle triangle scenarios
Technology	Using digital platforms and tools to support interactive learning	Integration of videos, audio, and images via the Wizer.Me platform
Engineering	Engaging students in a structured design task involving real-life construction challenges	Project to create a tower model applying geometric principles
Mathematics	Applying and understanding the Pythagorean Theorem through analytical and procedural tasks	Problem-solving activities and conceptual tasks related to triangle side relationships

**3. Development Stage**

Furthermore, the results of the storyboard are outlined in wizer.me. Table 2 is the initial design result of the drawing of the STEM-based digital worksheet that has been made in wizer.me, which is hereinafter referred to as prototype 1.

**Table 2.** Initial design results

Initial Design Results	Description
	The initial view of the digital worksheet consists of the subject identity and learning objectives that students will achieve.

Initial Design Results	Description
	In the digital worksheet, there is a video of contextual situations related to the benefits of learning the Pythagoras Theorem
	The STEM-based digital worksheet contains activity videos on how to make projects and miniature models
	In the digital worksheet, it can be seen that there are activities that link engineering with mathematics

At this stage, the researcher also conducted an expert validation process involving three validators, all mathematics education lecturers. The first validator was Dr. B.M., a lecturer in Mathematics Education at Universitas Sriwijaya (UNSRI). The second validator was Dr. S.A., a lecturer in Mathematics Education at UIN Raden Fatah Palembang. The third validator was A.O.L., M.Pd., a lecturer in Mathematics Education at Syahyakirti University, Palembang. The validation focused on four aspects: content, construction, language, and ICT. These four aspects were assessed using a questionnaire consisting of 20 items.

Table 3 shows the results of the expert validation. Based on Table 3, the average validity percentage of teaching materials is 83.68%, so it can be concluded that the teaching materials in the form of STEM-based digital worksheets developed by the researcher have been categorized as very valid. Although it has been categorized as valid, several aspects still need improvement based on feedback from the expert validation stage. Table 4 presents the improvements based on the suggestions provided by the validators.

**Table 3.** Expert validation results on STEM-based digital worksheet

Aspect	Indicator	Percentage
Content	Material aligns with Phase D of the Independent Curriculum	86.7
	Material aligns with stated learning objectives	86.7
	Questions are structured systematically from easy to difficult	86.7
	Integration of facts, concepts, and principles with STEM	73.3
	The use of science, technology, and engineering is visible in mathematical learning	86.7
Construction	Completeness of components (title, identity, objectives, steps)	86.7
	Contexts are appropriate to Phase D student characteristics	86.7
	Font type and size are consistent and appropriate	93.3
	Situations are interesting and challenging	86.7
	Visuals (images/videos) match the learning content	93.3
ICT	Layout is presented consistently	86.7
	Videos are interesting to students	93.3
	Videos are based on STEM content	86.7
	Videos/animations motivate students to learn	80.0
	All features function properly	86.7
Language	Sentences used are effective	73.3
	Terms used are from the Mathematics Education domain	73.3
	Language is polite and aligns with educational norms	86.7
	Language follows Indonesian grammar rules (PUEBI)	66.7
	Language is communicative and suitable for junior high school students	73.3
Average		83.68

**Table 4.** Comments and suggestions along with revision decisions

Comments/suggestions	Revision Decision
In the video of the problem/context situation, it should not be too long	The learning video has been revised.
Some redacted questions are still not appropriate, so the questions need to be corrected	The question has been corrected according to the suggestion
There should be questions that lead students to find concepts inductively.	Several questions were added that led students to find the concept first.
Continuity in writing letters on questions makes them more readable.	It has been fixed as suggested
In a STEM-based digital worksheet, there are still many words that are wrong in the recovery of uppercase and lowercase letters. And there are still many typos.	The STEM-based digital worksheet has been re-read, and then the wrong words are re-read in the case and case transcription. And there are still many typos that have been fixed
The troubleshooting instructions are made clearer and easier to understand.	Instructions for use number 3 has been corrected after the advice that has been given

The validation results showed an overall score of 83.68%, indicating a high level of appropriateness in content, instructional design, technology integration, and language use. This result aligns with the findings of Harun et al. (2024), who developed Google Form-based worksheets and found similar validity levels when the design was user-centered and adapted to the learners' needs. Juliana et al. (2024) also emphasized that digital worksheets are more effective when they support learner

autonomy and include features that allow self-paced exploration. The current study integrated such features through multimedia prompts and structured task scaffolding.

#### 4. Implementation Stage

After carrying out validation with experts, the next stage is implementation. At this stage, it consists of three parts: testing with one teacher and testing on one student for each cognitive level. The last part is to test a small group of students regarding learning styles, cognitive levels, and thinking habits.



**Figure 1.** One-to-one trial

The test was conducted with the teacher and one student representing each cognitive level to evaluate the developed STEM-based digital worksheet and to observe whether students encountered any difficulties while using it. Table 5 presents the results of observations related to students' difficulties in working with the STEM-based digital worksheet.

**Table 5.** Difficulties and comments of students in completing digital worksheets

Difficulties/Student Comments	Revision Decision
Students are unable to understand what important information is contained in the video of the cat on the roof.	Added hints for students to identify contextual problems
The project of building the Tower is too difficult if students complete it independently.	In learning, it is planned to be carried out in groups
There are too many problems of understanding and consolidating concepts that cannot be solved within 2 hours of lessons	The question of understanding and consolidation is reduced in number
The questions are categorized as easy, it's just that there are too many	The number of questions is reduced, but the form of questions is made in stages from easy to difficult.

The difficulties students experienced while working on the STEM-based digital worksheet served as input for revising it before testing it with a small group of students. After the revised STEM-based digital worksheet was deemed valid, it was tested on six SMP Negeri 4 Lubai Ulu students, who were divided into two groups based on their learning styles, cognitive levels, and thinking habits.



**Figure 2.** Small group trial

The lesson plan that has been prepared enables small group learning activities that are like real learning. After students work on a STEM-based digital worksheet, they are given a questionnaire to assess their practicality. The questionnaire consists of 10 questions, including questions about its attractiveness and ease of access. Below is a table of the STEM-based digital worksheet practicality questionnaire results.

**Table 6.** Practicality of STEM-based digital worksheet

Practicality Indicator	Percentage	Criterion
The STEM-based digital worksheet is easy to use	80.0	Practical
The display of the STEM-based digital worksheet is visually appealing	76.7	Practical
I can use the STEM-based digital worksheet independently or collaboratively	76.7	Practical
The images in the STEM-based digital worksheet are clear and easy to understand	90.0	Very Practical
The videos in the STEM-based digital worksheet are easy to understand	93.3	Very Practical
The videos in the STEM-based digital worksheet help me understand the Pythagorean Theorem and how to solve it	90.0	Very Practical
The typeface used in the STEM-based digital worksheet is easy to read	76.7	Practical
The sentences in the STEM-based digital worksheet are concise and to the point	80.0	Very Practical
The sentences in the STEM-based digital worksheet are easy to understand	86.7	Very Practical
The sentences in the STEM-based digital worksheet are clear and free of ambiguity	73.3	Practical
Average	82.33	Practical

Based on Table 6, the average percentage of the practicality of STEM-based digital worksheets is 82.33%. The teaching materials are categorized as practical if the rate of practicality is more than 75%. Because the percentage of practicality obtained is 82.33%, it can be concluded that STEM-based digital worksheets, which have been developed, have been categorized as practical.

Regarding practicality, the digital worksheets received an average score of 82.33%, reflecting students' positive responses toward ease of use, clarity, and overall engagement. These findings are consistent with Wahyuni et al. (2021), who reported increased student motivation and accessibility when digital worksheets were embedded with interactive guidance. In particular, this study's contextual videos and

visual supports played a crucial role in helping students comprehend abstract mathematical concepts. These findings also corroborate the review by Riza et al. (2023), which concluded that multimedia elements such as animation and narration significantly enhance students' understanding of science and mathematics.

A field test was conducted in a classroom setting involving 30 Grade VIII students to evaluate the potential effectiveness of the STEM-based digital worksheet. The students were asked to solve contextual mathematical problems that required applying the Pythagorean Theorem. Their problem-solving performance was assessed using a rubric adapted from Polya's four stages: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. Each stage was scored on a scale of 1 to 5, with a maximum of 20 points per student.

**Table 7.** Students' performance across each problem-solving stage

Polya Stage	Max Score	Average Score	Achievement (%)	Category
Understanding the problem	5	4.1	82.00	Good
Devising a plan	5	3.8	76.00	Fairly Good
Carrying out the plan	5	3.7	74.00	Fairly Good
Reviewing the solution	5	3.4	68.00	Needs Improvement
Total	20	15	75.00	Potentially Effective

Table 7 indicates that students performed best in identifying and understanding the problem (82%), consistent with the emphasis on contextual comprehension supported by the video and visual prompts in the digital worksheet. The average performance in the planning (76%) and execution (74%) stages reflects the student's ability to formulate strategies and apply the Pythagorean Theorem, albeit with some variability. However, performance in reviewing and evaluating the solution was the lowest (68%), indicating that reflective thinking and metacognitive skills require further development.

Qualitative analysis of students' written work and observations during the task revealed that high-performing students could clearly identify given and unknown values, represent the triangle visually, select the appropriate mathematical formula, and complete the calculations accurately. Some students also demonstrated the ability to check their results or explain the reasoning behind their answers. Conversely, several students omitted the final step of interpreting the result within the problem's context or failed to verify the correctness of their answers, which aligns with the relatively lower average in the final Polya stage.

## 5. Evaluation Stage

The evaluation phase represents the final stage in the ADDIE development process, focusing on assessing the overall quality and educational impact of the STEM-based digital worksheet after implementation. This stage consolidates findings from the expert validation, one-on-one and small-group trials, and classroom implementation with 30 students. Evaluation was conducted through both quantitative and qualitative approaches to determine the product's validity, practicality, and potential effectiveness. The expert validation process resulted in an average score of 83.68%, indicating a high level of validity across four key dimensions: content quality, construction, language use, and ICT integration. Based on expert feedback, the

worksheet was revised to improve clarity, language consistency, and instructional scaffolding.

In terms of practicality, small-group student trials resulted in a score of 82.33%, reflecting students' positive perceptions of the worksheet's usability, visual appeal, and comprehensibility. Comments from students highlighted that the digital worksheet was easy to navigate and engaging and helped them work independently or in collaboration with peers. These results suggest that the product is technically functional and pedagogically user-friendly.

The evaluation's most critical component was assessing potential effectiveness in improving students' problem-solving abilities. Data from the classroom field test with 30 students showed an average problem-solving score of 75%, based on Polya's four indicators. Students demonstrated strengths in understanding problems and planning solutions, while some limitations were observed in reviewing and reflecting on their solutions. Qualitative observations and student responses confirmed that the digital worksheet helped activate key stages of problem-solving, especially when supported by multimedia elements such as contextual videos and real-world engineering challenges.

In summary, the evaluation findings confirm that the STEM-based digital worksheet developed in this study meets the criteria of a valid, practical, and potentially effective instructional tool. It supports instructional design standards and 21st-century learning goals, particularly in promoting student-centered, technology-integrated, and STEM-oriented mathematics learning.

More importantly, the results of classroom trials demonstrated that the digital worksheets guided students through essential steps in problem-solving. Students were observed identifying mathematical problems, planning appropriate solutions, implementing strategies, and reflecting on their results. These behaviors are consistent with the findings of Topsakal et al. (2022), who showed that STEM-based problem-solving improves students' critical thinking and engagement. Furthermore, research by Koçulu et al. (2022) confirmed that STEM interventions could enhance students' 21st-century competencies, especially in areas such as problem-solving, collaboration, and adaptive reasoning.

The outcomes of this study can be further explained through several established educational theories. First, Mayer's Cognitive Theory of Multimedia Learning suggests that learning is more effective when materials combine verbal and visual channels in a coherent and structured way. Using videos, images, and explanatory text in the digital worksheets aligns with the principles of dual-channel processing, coherence, and signaling (Sarailoo et al., 2022). In addition, Taxipulati and Hai-dong (2021) emphasized that well-timed feedback and clear structure in multimedia learning can increase students' cognitive efficiency and attention, which is relevant to how guidance was presented in the worksheet.

Second, applying STEM content supports both near and far transfer of learning. Long et al. (2020) emphasized that project-based learning and engineering design tasks help students apply academic concepts in real-life situations. In this study, the integration of engineering contexts, such as constructing a model of a tower using Pythagorean principles, created opportunities for students to relate mathematical concepts to tangible problem-solving experiences. Olufunke et al. (2022) also highlighted the significance of authentic tasks in promoting deeper learning and meaningful application.

Third, student engagement and independence were notably supported by the digital worksheet. According to Deci and Ryan's Self-Determination Theory (SDT), learning environments that support autonomy, competence, and relatedness can enhance intrinsic motivation. Juliana et al. (2024) showed that digital worksheets offering choice and flexible pacing promote learner autonomy, consistent with how students in this study responded positively to independent and collaborative use of the digital worksheets. Furthermore, Keller's ARCS model provides a motivational framework where elements such as attention-grabbing visuals and relevant contexts enhance student interest and satisfaction, both observed in the trial sessions (2023).

The Engineering Design Process (EDP) also served as a pedagogical framework within the digital worksheet structure. Students were guided through stages of identifying a problem, brainstorming ideas, planning solutions, executing their plans, and evaluating outcomes. This structure mirrors the steps of EDP as discussed in the reviews by Sudrajat et al. (2022) and Winarno et al. (2020), who noted that EDP helps scaffold students' metacognitive skills and supports problem-based inquiry in STEM education.

The findings of this study have important implications for classroom practice and curriculum implementation. From a practical standpoint, the digital worksheets developed in this research provide a viable learning tool for teachers to implement project-based STEM activities within mathematics instruction. It is particularly relevant for the Indonesian Merdeka Curriculum, which emphasizes flexibility, digital literacy, and learner-centered pedagogy.

Theoretically, this study adds to the research on technology-enhanced STEM education by demonstrating that digital worksheets can effectively support students' problem-solving skills. Unlike previous studies focusing on motivation or creativity (Arifin et al., 2021; De Vink et al., 2022) This research explicitly emphasizes problem-solving as a core mathematical competence (Hidayati et al., 2020). As such, the study fills an important gap by showing how STEM design principles, multimedia theory, and instructional design can be synthesized to produce effective learning resources.

This study also provides a model for further development. Future instructional designers can use this approach to create similar materials for other mathematical concepts or science subjects. Moreover, the structure of the digital worksheets aligns well with principles of formative assessment (Toma et al., 2023) and self-directed learning (Chen et al., 2024). Both of which are increasingly relevant in digital education environments.

### **Limitations and Directions for Future Research**

Although the study yielded promising results, several limitations should be acknowledged. First, the study was conducted in a single school with few participants. As a result, the findings may not be generalizable to other contexts without additional studies in more diverse settings. However, this scope is acceptable in early-phase development research, focusing on validity and practicality rather than statistical generalization (Rahayu et al., 2023).

Second, the effectiveness of the digital worksheets in improving learning outcomes was not measured through experimental or quasi-experimental designs. Therefore, future research should incorporate pre-test and post-test designs, using gain scores or ANCOVA, to quantify learning impact. Third, this study focused on problem-solving skills as the primary cognitive target. Other dimensions, such as creative thinking, mathematical representation, or collaborative problem-solving, were

not directly measured and should be considered in future studies. Lastly, implementing digital tools in schools still depends on access to internet connectivity and adequate devices, which remain infrastructural challenges in some educational contexts.

## CONCLUSION

This study aimed to develop valid and practical STEM-based digital worksheets to enhance junior high school students' problem-solving skills, particularly on the Pythagorean Theorem. The research findings indicate that the developed digital worksheets meet the criteria of validity with an average score of 83.68%, as confirmed through expert validation on content, instructional structure, technological integration, and language use. In terms of practicality, the product received an average score of 82.33%, reflecting a positive student response regarding usability, clarity, and engagement. Integrating multimedia elements, real-world STEM contexts, and engineering design tasks successfully facilitated students' involvement in identifying problems, designing solutions, and evaluating outcomes, thereby supporting the intended learning objectives.

Based on these results, it is recommended that teachers consider adopting STEM-based digital worksheets as a supplementary learning tool, especially in problem-based and technology-integrated instructional models. For broader implementation, schools and policymakers should also support digital infrastructure and professional development initiatives that empower educators to design and use similar tools. Future research may extend this study by conducting experimental trials to measure the effectiveness of the digital worksheets on student learning outcomes, including other higher-order thinking skills such as creativity, reasoning, or representation. Future product development can also explore integration with learning management systems or adaptation across various mathematics topics and grade levels.

## ACKNOWLEDGMENTS

This research is funded by the Ministry of Education, Culture, Research, and Technology, in the Master's Thesis Research and based on Decree Number 0459/E5/PG.02.00/2024 and Agreement/Contract Number 090/E5/PG.02.00.PL/2024

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