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Development of Multimedia-Assisted E-LKPD Based on Problem-Based Learning to Improve Mathematical Problem-Solving Abilities and Independent Learning of Junior High School Students

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Abstrak

Penelitian ini bertujuan untuk mengembangkan E-LKPD berbantuan multimedia berbasis masalah yang valid, praktis, dan efektif dalam meningkatkan kemampuan pemecahan masalah matematis serta kemandirian belajar siswa SMP. Selain itu, penelitian ini juga menganalisis peningkatan kemampuan pemecahan masalah matematis siswa melalui penggunaan E-LKPD tersebut. Metode yang digunakan adalah penelitian pengembangan dengan model ADDIE, yang dilaksanakan di SMP Negeri 11 Medan. Instrumen penelitian meliputi lembar validasi ahli, angket respons guru dan siswa, tes kemampuan pemecahan masalah matematis, serta angket kemandirian belajar. Hasil penelitian menunjukkan bahwa E-LKPD yang dikembangkan memenuhi kriteria "Sangat Valid", "Praktis", dan "Efektif", serta berpengaruh signifikan terhadap peningkatan kemampuan pemecahan masalah matematis dan kemandirian belajar siswa. Hal ini ditunjukkan oleh (a) hasil uji paired-samples t-test dengan nilai signifikansi 0,000 < 0,05, (b) nilai N-Gain untuk kemampuan pemecahan masalah matematis sebesar 0,589, dan (c) nilai N-Gain untuk kemandirian belajar sebesar 0,411, dengan mayoritas siswa berada pada kategori peningkatan "Sedang". Dengan demikian, penggunaan E-LKPD berbantuan multimedia terbukti mampu meningkatkan kemampuan pemecahan masalah matematis siswa secara signifikan.

Kata Kunci: *E-LKPD, Multimedia, Pembelajaran Berbasis Masalah, Pemecahan Masalah Matematis, Kemandirian Belajar*

Abstract

This study aims to develop a valid, practical, and effective multimedia-assisted problem-based E-LKPD (Electronic Student Worksheet) to improve mathematical problem-solving abilities and learning independence among junior high school students. In addition, this study analyzes improvements in students' mathematical problem-solving abilities through the use of the E-LKPD. The method used is development research with the ADDIE model, which was implemented at SMP Negeri 11 Medan. The research instruments include expert validation sheets, teacher and student response questionnaires, mathematical problem-solving ability tests, and learning independence questionnaires. The results of the study indicate that the developed E-LKPD meets the criteria of "Very Valid", "Practical", and "Effective", and has a significant effect on improving students' mathematical problem-solving abilities

and learning independence. This is indicated by (a) the results of the paired-samples t-test with a significance value of 0.000 < 0.05, (b) the N-Gain value for mathematical problem-solving ability of 0.589, and (c) the N-Gain value for learning independence of 0.411, with the majority of students in the "Moderate" improvement category. Thus, the use of multimedia-assisted E-LKPD has been proven to be able to significantly improve students' mathematical problem-solving abilities.

Keywords: E-LKPD, Multimedia, Problem-Based Learning, Mathematical Problem Solving, Learning Independence.

A. Introduction

Mathematics is precise and ordered, supporting other sciences and advancing technology. Mathematics is a foundational subject that helps other sciences develop and comprehend ideas and conclusions. Mathematics is taught from primary to college. Students should learn to think, argue, and solve daily math problems. The five general features of mathematics learning outlined by the National (NCTM, 2020) Explain low student math scores. Students must study math. Math talents include problem-solving, reasoning and proof, communication, connections, and representation. Problem solving is an attempt to overcome a challenge to reach a goal that cannot be achieved immediately, according to (Polya, 1973). Problem-solving abilities are fundamental to mathematics education because they teach students to think rationally, critically, systematically, and creatively.

Students must learn many indicators that form the basis of mathematical problem-solving to acquire skills. First, understanding the topic requires students to read and evaluate it thoroughly and discover essential data and information. Second, planning the problem-solving process involves choosing the most efficient technique based on experience or established approaches. Third, pupils carefully follow the problem-solving plan. Finally, examining the steps to find other solutions. The results from the previous phase must be interpreted in this step to better understand and apply the solution. Students can solve mathematical issues and acquire lifelong logical and analytical thinking skills by understanding these indications. Based on observations conducted by researchers on Monday, April 28, 2025, the learning outcomes of students in grade IX-4 of SMP Negeri 11 Medan in mathematics are still relatively low, especially in mathematical problem-solving ability. Therefore, the results of the problem-solving ability test showed no students with high criteria, 27.58%, or 8 students, in the medium category, and 72.41%, or 21 students, in the low category. Overall, it can be concluded that students' cognitive problem-solving abilities at SMP Negeri 11 Medan are still relatively low.

The results of research by (Yuliyani, P., Sariningsih, R., Rohaeti, 2023) indicate that students' mathematical problem-solving abilities are still low. This low mathematical problem-solving ability is caused by students' lack of accuracy when reading descriptive questions, not paying attention to the teacher's explanations, and not understanding graphical questions. Students' reasoning styles regarding mathematical problems are difficult. Similarly, (Nabilah, K., Siregar, 2023)found that eighth-grade students' learning outcomes on flat-sided geometric shapes are still relatively low, particularly in problem-solving skills. This skill is crucial and necessary for survival in the face of increasingly dynamic challenges and problems in today's era.

In addition to cognitive factors, affective factors, including attitudes, interests, independence, and learning motivation, affect how children grasp and process math. Ahmad, A. H., Triana, E., & Damanik (2022) says that knowing students' affective development is crucial to successful learning. Self-regulated learning is effective. According to Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 65 of 2013 on Standards for Elementary and Secondary Education Processes, educational units must conduct learning interactively, inspiringly, enjoyably, and challengingly, motivating students to actively participate and providing sufficient space for initiative, creativity, and independence in accordance with their talents (Kemendikbud, 2013). Successful learning requires harmonic, efficient, and mutually supportive interactions between all elements. Therefore, active control and a scientific methodology are needed to make learning comprehensive and relevant for each person. A skill is autonomous math learning (Aziz, 2023).

Diana, P. Z., Wirawati, D., & Rosalia, (2020) define Self-Regulated Learning as an active and constructive process in which students set learning goals and monitor, regulate, and control cognition, motivation, and behaviour, which are driven by goals and adapted to the environment. Student independence in learning is increasingly critical to success, especially in math. Independent learning lets kids take charge, gain responsibility, and choose their own learning. Teacher attention and encouragement of student learning independence are crucial. (Dessuko, 2024) found that independent learners are more resilient, calmer, and critical thinkers. Independent learning emphasizes self-development and personal responsibility without outside influence. You need guts to take chances, initiative to start something, and experience to learn independently.

The researcher interviewed a mathematics instructor at SMP Negeri 11 Medan on Tuesday, November 5, 2024, and found that many kids are still unable to learn independently. (1) Few pupils study previous topics or read textbooks at home. Without independent study, they rely on the teacher's explanations. (2) Though the problem has been reviewed, students often wait for the teacher to clarify or offer instructions before solving practice problems. (3) Students are passive when asked to discuss in groups and wait for more active friends to start. (4) Students seem bewildered and replicate their peers' responses to complex problems rather than trying fresh ones. (5) Many students refuse or feel incapable of delivering discussion results or solving problems in front of the class without support from friends or the teacher. These findings indicate that pupils' math independence is minimal (Daniyati, A., Wijaya, R., & Setiawan, 2023).

Before teaching, educators employ learning tools. Students and teachers perform comprehensive, systematic activities. A syllabus, Lesson Implementation Plan (RPP), Student Worksheets (LKPD), Evaluation Instruments or Learning Outcome Tests (THB), learning media, and student textbooks are utilized by teachers (Ferdinan., Karuru, P., Handoko, Y., 2024). Every instructor should examine learning tools because they affect educational success. Thus, teachers must optimize technology and use it to create Electronic Student Worksheets (E-LKPD) to address weak mathematical problem-solving skills and student learning independence, ensuring quality learning. Interactive E-LKPD, according to (Subakti, D., Marzal, J., & Hsb, 2021) These are learning tools or facilities that give students feedback on their efforts, engaging them in two-way engagement with the E-LKPD, simplifying instructional messages, and improving math learning. E-LKPD offers a significant advantage in developing student learning independence by allowing flexible access to resources anytime and anywhere, unlike

conventional learning approaches (Rahmawati, F., & Nindiasari, 2021). (Sari, A., Revita, 2022) agrees that E-LKPD can be more interactive and interesting. Multimedia elements like films, graphics, and quizzes stimulate students to learn. Thus, increasing E-LKPD, a learning tool, may increase student learning outcomes, notably mathematical problem-solving and independence.

According to (Hendrikson R Panjaitan, 2023), problem-based learning makes education more relevant to life outside of school, trains students to solve problems critically and scientifically, and trains students to think critically, analytically, creatively, and comprehensively by highlighting problems from various perspectives. Actively solving real problems in PBM helps kids learn. (Husna, N. H., Marzal, J., 2022) states that PBM engages students in the learning process, improving their comprehension. Adding multimedia-assisted E-LKPD (Electronic Student Worksheet) to problem-based learning helps students build mathematical problem-solving skills and learning independence. Improved problem-solving skills help students become more confident and autonomous in their learning, while strong learning independence helps students solve mathematical difficulties. (Panjaitan, S. N., Mansyur, A. Syahputra, 20233) found that strong learning tools made the problem-solving-based E-LKPD legitimate, practical, and effective. This E-LKPD at SMP IT Indah Medan improves students' mathematical problem-solving and learning independence. According to (Palupi, F. R., 2021), the multimedia-based E-LKPD harmonic vibrations learning media is ideal for high school students' mastery and independence. E-LKPD 's multimedia-based approach improved student learning freedom and topic mastery moderately.

B. Research Method

Research and Development is used. Research and development ensure responsibility by creating or improving a product, according to (Nana Laode Sukmadinata, 2018). This work produced a multimedia-assisted E-LKPD learning tool. The ADDIE idea development model by Robert Maribe (Branch, 2009) is used to guide the development process. It has five steps: Analysis, Design, Development, Implementation, and Evaluation. This research will be done in SMP Negeri 11 Medan, Jl. Budi Kemenangan No. 24, Pulo Brayan Kota, Medan City, North Sumatra. Research occurs in the odd semester of 2025/2026. This study includes 25 SMP Negeri 11 Medan grade IX-7 students. This study examines Multimedia-Assisted E-LKPD. This study uses Branch's ADDIE development model with some modifications:

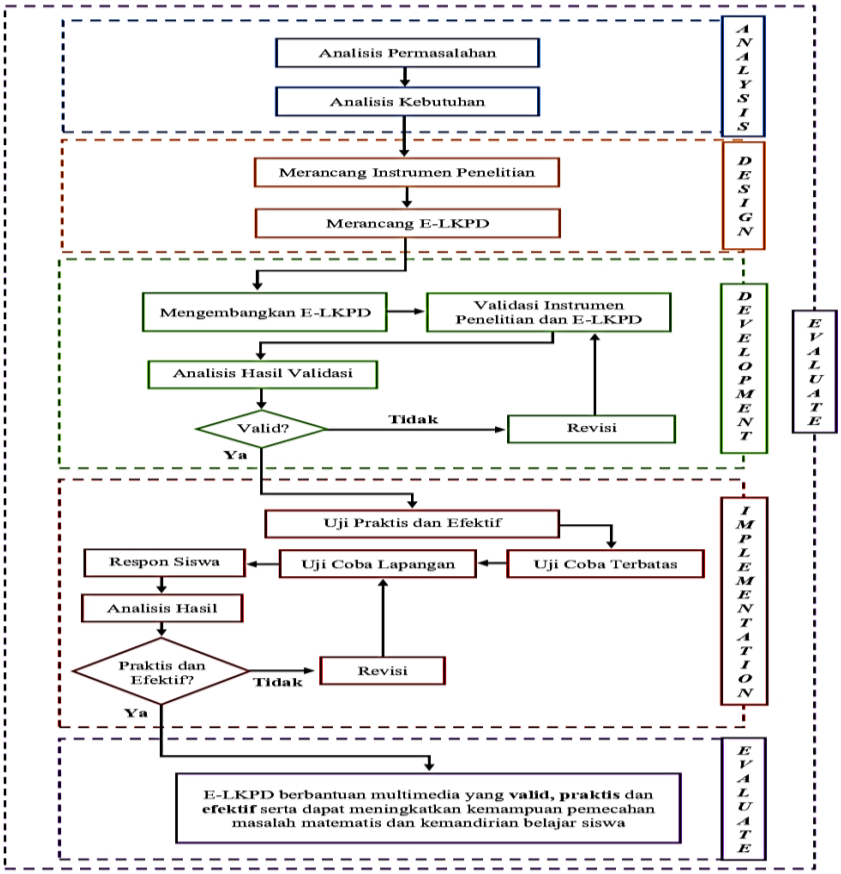

Figure 1. Steps of the ADDIE Development Model

Product development follows these steps:

1. Analysis Phase

Problem analysis identifies and clarifies student issues that require novel multimedia-assisted E-LKPD (Electronic Student Worksheet) solutions. Math teachers were interviewed, and teaching and learning activities were observed for this analysis. Researchers studied the educational environment, facts, and field learning to identify the best solution.

The investigation indicated that pupils wanted interactive, accessible, and active learning tools. Thus, learning aids were created to help students understand mathematical ideas, improve problem-solving skills, and cultivate independent learning in accordance with SMP Negeri 11 Medan's curriculum.

2. Design Phase

In the design stage, precise solutions to recognized challenges are essential. The analysis suggests creating a multimedia-assisted E-LKPD based on a problem-based learning approach to increase mathematical problem-solving and student independence. At this level, researchers planned learning utilizing the E-LKPD (currently under evaluation) and created materials in addition to product design.

3. Development Phase

This research developed by turning the learning media design created during the design stage into a school-ready product. Researchers created a multimedia-assisted E-LKPD tailored to student characteristics and focused on prism and pyramid material. E-LKPD challenges that addressed problem-solving abilities, supporting components, and visual and audiovisual resources like photos, videos, and

audio that aligned with key competencies and learning indicators were collected and compiled to start the development process. To simplify student use, these materials were integrated into the E-LKPD through media production and processing, including display settings, animation editing, and navigation button design.

4. Implementation Phase

To evaluate multimedia-assisted E-LKPD for mathematics learning, practicality and efficacy were prioritized during deployment. The E-LKPD 's practicality was assessed by students' and teachers' ratings on its ease of use, including material access and assignment completion time. A questionnaire was sent to three ninth-grade math teachers and research participants.

5. Evaluation Phase

The evaluation phase concludes the ADDIE development model. It evaluates if the E-LKPD promotes students' mathematical problem-solving and autonomous learning and meets practicality and effectiveness requirements. Formative and summative evaluations occur. Formative evaluation occurs at each phase in the ADDIE model development process, while summative evaluation occurs after learning. A post-test and student and instructor surveys evaluating the E-LKPD are included. This evaluation assesses E-LKPD feasibility and efficacy.

C. Result and Discussion

To achieve these objectives, this research adopted the ADDIE development model, which consists of five stages. The final products include a Lesson Implementation Plan, Electronic Student Worksheets (E-LKPD), a mathematical problem-solving ability test instrument, and a student learning independence questionnaire. The results of the data analysis and research findings at each stage of development are presented below. This research was conducted with reference to the ADDIE model, which consists of five stages, namely analysis, design, development, implementation, and evaluation, which are described as follows.

1. Analysis Phase

The analysis phase is conducted to formulate and identify needs in the learning process to produce high-quality E-LKPD. Activities at this stage include needs analysis and student character analysis, which will be described in Table 1 dan 2.

Table 1. Student Needs Analysis

No	Needs Aspect	Analysis Results	Development Implications
1	Learning Resources	Textbooks remain the primary learning resource and lack student interest.	Developing a multimedia-assisted E-LKPD as an alternative learning resource.
2	Learning Media	Media containing text, images, video, animation, and audio are needed.	The E-LKPD is designed with interactive multimedia.

3	Learning Models	Teachers need tools that support problem-based learning.	The E-LKPD content is structured according to Problem-Based Learning syntax.
4	Practice Questions	Students need questions that can train higher-order thinking skills.	Contextual problem-solving questions are provided.
5	Learning Independence	Students need media that can be studied independently both inside and outside the classroom.	The E-LKPD can be accessed via digital devices at any time.
6	Evaluation	Teachers need media that facilitates evaluation of the learning process.	The E-LKPD is equipped with activity-based exercises and evaluations.

Table 2. Analysis of student character

No	Needs Aspect	Analysis Results	Development Implications
1	Age	Students aged around 14–15 years (grade 9 of junior high school).	The material is presented in simple and communicative language.
2	Cognitive development	They are in the early formal operational stage, starting to be able to think abstractly but still requiring visual aids.	The material is complemented by illustrations, animations, and contextual examples.
3	Technological skills	Most students are familiar with using smartphones, laptops, and the internet.	The E-LKPD is designed digitally and is easy to operate.
4	Learning style	Students prefer learning that involves images, videos, and interactive activities.	Multimedia in the form of videos, images, animations, and audio is integrated into the E-LKPD.
5	Learning motivation	Motivation to learn mathematics is still low.	Engaging activities and real-life problems are presented to increase motivation.
6	Early abilities	Mathematical problem-solving skills are still low, based on diagnostic tests.	The material is structured from simple to complex problems.
7	Learning independence	Some students still rely on the teacher's explanations.	The E-LKPD provides study guides and independent activities.

Based on the analysis results, it can be concluded that the development of multimedia-assisted E-LKPD is the right solution to address the needs of mathematics learning at SMP Negeri 11 Medan. This E-LKPD is expected to be able to optimize the use of available technological facilities, present material interestingly and contextually, and encourage active student involvement. By integrating problem-based

learning and multimedia-assisted E-LKPD, it is expected to improve mathematical problem-solving skills and student learning independence.

2. Design Phase

The design step helps solve difficulties found in the analytical phase. The analysis suggested creating a multimedia-assisted E-LKPD (Electronic Student Worksheet) to improve students' mathematical problem-solving and learning independence. In addition to designing the product, the researcher created a Learning Implementation Plan (RPP) and designed instruments for development, implementation, and evaluation.

The researcher studied relevant literature to construct the multimedia-assisted E-LKPD based on problem-based learning. These sources included mathematical textbooks, scientific journals, theses, dissertations, and other materials on prisms and pyramids.

Additionally, the researcher designed the E-LKPD cover, content, instructional videos, and supporting pictures. Audio and other supporting components were carefully chosen to create an appealing and instructive multimedia-assisted E-LKPD. To clarify content, improve presentation, and motivate students to learn math, the design was beautiful and well-designed. Each instrument's design is described below:

The multimedia-assisted E-LKPD (Electronic Student Worksheet) cover uses blue and yellow colours and prism and pyramid illustrations, along with other supporting images, to make it appealing. The colour blue conveys trust, peace, and comfort, according to (Laela, K. V., Fatih, M., dan Wafa, 2024). According to (Mawardi, K., Arjudin., Turmuzi, M., & Azmi, 2022), Yellow symbolizes happiness, luck, and excitement. Yellow attracts kids' attention, boosts mood, encourages learning, and boosts daily activity. Children's cognitive and emotional development requires proper visual stimulation, which explains why children prefer bright colours like red, yellow, and blue because they are more engaging and appealing.

Figure 2. Media Display

The results of the design stage are in the form of Prototype I E-LKPD assisted by multimedia based on Problem-Based Learning on the material of Flat-Sided Space Structures (Prisms and Pyramids). Prototype I consists of several components, namely the cover page, instructions for use, learning objectives, apperception, presentation of contextual problems, learning materials combined with multimedia, student activities according to PBL syntax, problem-solving exercises, reflection, and evaluation.

3. Development Phase

The development stage in this research is the process of realizing the design developed during the design phase. At this stage, two main activities are carried out. First, the researcher prepares all supporting instruments such as questionnaires, test questions, lesson plans, and various media elements, which are then combined into a single unit. Second, an assessment or validation process is carried out by experts on all components that have been prepared to ensure the feasibility of the E-LKPD. The following presents the results of the validation and revision of the lesson plans, E-LKPD, questionnaires, and test instruments that have been developed:

Table 3. Expert validation results

No.	Rated aspect	Average	Category
1	Lesson plan	3,72	Valid
2	E-LKPD	3,68	Valid
3	Teacher Response Questionnaire	3,75	Valid
4	Student Response Questionnaire	3,94	Valid
5	Pre-Test	3.68	Valid
6	Post-Test	3.46	Valid
7	Learning Independence Questionnaire	**3.81**	Valid

Before the learning tools were implemented in the trial phase, all tools were first validated by three validators consisting of a material expert, a media expert, and a learning expert. Validation was conducted to determine the feasibility of the tools developed, including the Teaching Module/RPP, multimedia-assisted E-LKPD, teacher response questionnaires, student response questionnaires, pre-test instruments, post-test instruments, and learning independence questionnaires. Based on Table 3, the expert validation results concluded that this research instrument met the required quality standards in terms of construction, content, language, and the accuracy of its indicators. With a total average within the valid category, this instrument has good credibility for use as a data collection tool. The use of this validated instrument is expected to ensure the validity of the research results and provide an objective picture of student improvement after the learning process.

4. Implementation Phase

After expert input-based modifications and validation of all instruments and the E-LKPD, the research moved to deployment. A trial of the E-LKPD and test instruments assessed their practicality and learning effectiveness. The trial in this study has two stages: a limited and a field. The product's first practicality was tested on a small group of pupils. Next, all students in one class participated in a field

trial to better understand product utilization in learning. Trial implementation results. The effectiveness test results were analyzed to determine the extent to which the multimedia-assisted E-LKPD developed improved students' mathematical problem-solving skills and learning independence. The effectiveness of the learning tools in this study was assessed based on the results of students' mathematical problem-solving abilities using pre-tests and post-tests, paired sample t-tests, and N-gain analysis. The pre-test results indicated students' initial mastery of mathematical problem-solving skills and learning independence. A description of the pre-test data is presented in Table 4.

Table 4. Post-Test Data of Problem-Solving Ability

Description	*Post-Test*		Improvement
	UCL I	UCL II	
Lowest Value	67.7	72.9	5.2
Highest Value	83.3	95.8	12.5
Average ($\bar{x}$)	73.3	86.9	13.6

Table 5. Student Learning Independence Questionnaire Data 2

Description	After Learning		Improvement
	UCL I	UCL II	
Lowest Value	67	76	9
Highest Value	90	92	2
Average ($\bar{x}$)	77.50%	87.68%	10.18%

Furthermore, a paired-samples t-test was conducted based on the results of the Pre-Test and Post-Test to determine whether or not there were significant differences in students' mathematical problem-solving abilities and learning independence after using multimedia-assisted E-LKPD. The results of the t-test can be seen in Table 6 and Table 7.

Table 6. Results of The Paired-Samples T-Test In Field Trial I

Paired Samples Test					
		Paired Differences			
		95% Confidence Interval of the Difference			
		Upper	t	df	Sig. (2-tailed)
Pair 1	*Pre-Test* – PostTest_KPM	-7.025	-6.567	24	.000
Pair 1	*Pre-Test* – PostTest_KBS	-6.859	-6.814	24	.000

Table 7. Results of The Paired-Samples T-Test In Field Trial II

Paired Samples Test					
		Paired Differences			
		95% Confidence Interval of the Difference			
		Upper	t	Df	Sig. (2-tailed)
Pair 1	*Pre-Test* - Post Test	-17.2026	-12.635	28	.000
Pair 1	*Pre-Test* - Post Test	-6.669	-7.823	28	.000

According to Tables 6 and 7, the paired-samples t-test findings for Field Trials I and II show a significance value (Sig. 2-tailed) of 0.000 < 0.05 for mathematical problem-solving ability and student learning independence. Ha is approved, and Ho is rejected, suggesting a significant change between pre-test and post-test scores after using the multimedia-assisted E-LKPD based on Problem-Based Learning.

In Field Trial I, the multimedia-assisted E-LKPD improved students' mathematical problem-solving and learning independence, but not to the predicted level. After Field Trial II modifications to the multimedia-assisted E-LKPD, the paired-samples t-test improved further. The paired-samples t-test shows that multimedia-assisted E-LKPD based on Problem-Based Learning improves students' mathematical problem-solving and learning independence. Pre- and post-test N-Gain data were also collected. Multimedia-assisted E-LKPD was tested for its ability to improve students' mathematical problem-solving and learning independence using the N-Gain value. The average of each student's N-Gain exam in Field Trials I and II was used to assess their mathematical problem-solving and learning independence. The N-Gain examination assessed students' mathematical problem-solving and learning independence. The details of the N-Gain test results for individual mathematical problem-solving abilities are presented. Therefore, data on the improvement in mathematical problem-solving abilities, when viewed based on N-Gain values, are only presented in Field Trial II. These data are presented in Table 8.

Table 8. N-Gain Test Based on Problem-Solving Ability Indicators in Field Trial

Indicators	Average value				N-Gain	Category
	Pre-Test	Category		Category		
Understanding the Problem	83.7	Completed	High	Completed	0.700	High
Planning a Solution	63.4	Incomplete	Medium	Completed	0.584	Medium
Solving the Problem	53.6	Incomplete	Medium	Completed	0.461	Medium
Looking Back	61.2	Incomplete	High	Completed	0.711	High

Average	85.9	Incomplete	Medium	Completed	0.614	Medium

Table 8 shows that the field trial optimally improved mathematical problem-solving skills based on the N-Gain values for each indicator. Students' ability to identify known and needed information in problems increased as the problem understanding indicator reached 0.700, a High N-Gain. The review indicator had an N-Gain of 0.711, indicating that students were better able to double-check procedures and solution findings. The planned solution indicator had an N-Gain of 0.584 and the problem-solving indicator 0.461, both Moderate.

This indicator improved significantly due to the multimedia-assisted e-LKPD based on problem-based learning. Each learning activity in the e-LKPD includes evaluative questions, answer checks, comparisons of solution options, and an opportunity to remedy errors before completing the assignment. Thus, pupils learn to verify their work regularly.

Multimedia also helped boost this indicator. The e-LKPD's animations, visual drawings, learning videos, and feedback help students identify flaws in their solution steps more easily than conventional learning. These visualizations allow students to compare their thought processes with the right procedures, making reviewing an essential element of learning.

Problem-Based Learning (PBL) analyzes and solves problems; therefore, these results make sense. Students conclude learning by reflecting on the discussion, receiving comments from other groups, and assessing the tactics' strengths and limitations. This activity immediately encourages students to review solutions and shows problem-solving tactics work. Thus, the review indicator improved more than others.

This behavior can be explained by metacognitive theory. Metacognitive regulation the ability to monitor, activate, and refine thinking includes reviewing solutions. Multimedia-assisted e-LKPD allows students to self-monitor through reflective questions, self-evaluation, and feedback. Thus, students' metacognitive awareness grows, making them more comfortable checking problem-solving techniques and results. This study also shows that poor review capacity is conditional on the learning design. Student review ability can improve when scaffolding, reflection, and feedback are clearly provided during solution evaluation. Thus, this study's high N-Gain score for the "reflection" indication shows that the multimedia-assisted E-LKPD based on problem-based learning changed students' habits from searching for answers to analyzing the problem-solving process and results.

Several previous studies support this finding. (Hidayat, W., & Sariningsih, 2018) found that problem-based learning improves students' reflection skills by making them explore problem-solving procedures. (Fitriani, N., Suryadi, D., 2021) found that interactive, multimedia-assisted E-LKPD improves students' metacognitive skills through feedback and structured reflection. This indicates that students have improved in strategy and problem-solving, but they need to improve further to reach a higher level. The problem-solving questions that students worked on are shown in the following figure:

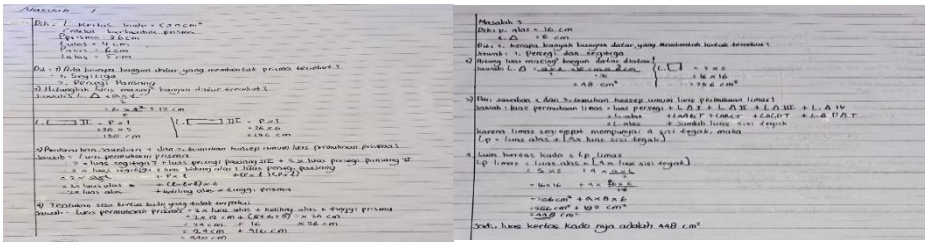

Figure 3. Problem solving questions

All markers of mathematical problem-solving abilities improved, with two "High" and two "Medium" readings. This suggests that multimedia-assisted E-LKPD can improve students' mathematical problem-solving equitably.

Table 8. Changes in Learning Independence Ability Per Indicator in Field Trial

Indicators	Average Score				N-Gain	Category
	Before	Category		Category		
Responsibility	87.93	Very Good	Medium	Excellent	0.534	Medium
Initiative	80.93	Good	Medium	Excellent	0.558	Medium
Self-Confidence	70.69	Fairly Good	Medium	Excellent	0.630	Medium
Independence from Others	68.53	Fairly Good	Medium	Good	0.463	Medium
Decision-Making Skills	80.60	Good	Medium	Excellent	0.434	Medium
Average	77.74	Good	Category	Excellent	0.524	Medium

Table 8 shows that multimedia-assisted E-LKPD increases student learning independence across all indicators. Responsibility went from 87.93% to 92.24% (4.31%). Initiative increased 8.4% from 80.93% to 89.33%. The self-confidence measure rose 15.95% from 70.69% to 86.64%. The independence indicator rose 12.72% from 68.53% to 81.25%. Finally, the decision-making ability indicator rose 6.68% from 80.60% to 87.28%. Multimedia-assisted E-LKPD improves students' learning freedom, responsibility, initiative, self-confidence, independence, and decision-making. The Field Trial study found that the multimedia-assisted E-LKPD improved students' mathematical problem-solving and learning independence. After engaging in the multimedia-assisted E-LKPD, students' learning independence, N-Gain score, and mathematical problem-solving skills improved significantly. The developed E-LKPD can be utilized as an alternate learning tool to enhance active, interactive, and student-centered mathematics learning.

The researchers believe this improvement occurred because e-LKPD serves as open digital material and a learning guide that helps students construct knowledge independently through contextual problem-solving, information exploration, reflection, and learning outcome evaluation.

Independent indicators also rose. Researchers say this is because e-LKPD gives students independent learning instructions, problem-solving stages, visual illustrations, and learning resources. This

multimedia helps students understand the content without teacher or peer explanations. Students acquire control over their learning when independent learning frequency increases. (Zimmerman, 2022) stated that an atmosphere that promotes independent learning helps students organise, monitor, and manage their learning.

Students' decision-making abilities increased during problem-based learning because they were exposed to different solution strategies. They must find relevant facts, choose a solution technique, justify it, and reflect. Critical thinking and autonomous decision-making are constantly practiced. (Hmelo-Silver, 2023) states that problem-solving-based learning helps students analyse circumstances, produce solutions, and choose the best one using logic.

All self-directed learning indicators improved when Problem-Based Learning was combined with multimedia-assisted E-LKPD to produce a more active, interactive, and student-centered learning environment. Students learn to manage their learning through individual investigation, reflection, evaluation, and problem-solving. Thus, multimedia technology and a systematic learning design that promotes responsibility, initiative, self-confidence, independence, and decision-making through meaningful learning experiences improved self-directed learning in this study.

5. Evaluation Phase

The evaluation stage aims to assess the quality of the learning tools developed during the learning process. At this stage, researchers identify the level of learning success and provide recommendations for improvements to the tools and implementation. An evaluation was done during implementation to ensure that the E-LKPD met practical and effective learning criteria and improved learning objectives. The implementation results in grades IX-6 and IX-7 of SMP Negeri 11 Medan, with 29 and 25 students, respectively, revealed many problems. From the researcher's perspective, the obstacles that emerged during the implementation phase were students' adaptation process to the use of multimedia-assisted E-LKPD based on Problem-Based Learning (PBL), which differed from conventional learning. Students who were previously accustomed to receiving direct explanations from teachers needed time to adjust to learning that required independent exploration, discussion, and problem-solving. As a result, some students experienced difficulties understanding E-LKPD instructions, managing group discussions, and communicating problem-solving results. This condition aligns with (Fitria, T. N., & Jatmiko, 2022)who explained that new learning environments can increase cognitive load in the early stages of learning. Therefore, revisions were made to the lesson plans, refinement of E-LKPD instructions, addition of discussion activities, and extension of learning time to provide students with a more optimal opportunity to adapt. These results are also supported by (Zainuddin, Z., Wahyudi, A., 2024) who stated that formative evaluation in development research aims to identify product weaknesses so that revisions can be made to increase the practicality and effectiveness of the learning tool. Thus, improvements made during the evaluation phase were a contributing factor to improving the quality of E-LKPD implementation in subsequent trials.

Students were unfamiliar with multimedia-assisted E-LKPD in learning. This confused some pupils, especially when faced with challenges without a teacher's explanation. This wasted learning time. Some pupils had trouble understanding the LKPD instructions, which hindered their assignment completion.

Groups still struggled to accurately articulate their discussion conclusions, showing that their understanding and problem-solving skills needed work.

The evaluation results were used to revise the lesson plan (RPP) to better integrate E-LKPD into each learning stage. Designs more participatory exercises, clearer guidance in student worksheets (LKPD), more structured group discussions, and more meetings from four (7JP) to five (9JP) improved learning. In addition, the researcher needed numerous students to observe the pre- and post-tests. This aimed to assure an orderly test-taking process, avoid cheating, and accurately assess students' abilities. With these evaluations and enhancements, the next round of learning should operate more smoothly and meet goals.

Discussion

Several variables made the learning tools valid. First, the E-LKPD and RPP were content-valid. Content validity requires learning tools to meet curricular criteria, specifically the core competencies (KI) and basic competencies (KD) that students must learn from the material. According to (Nabilah, K., Siregar, 2023), a learning tool is content-valid when it can measure learning objectives that match the lesson's content. Content validity is sometimes called curricular validity. Second, multimedia-assisted E-LKPD tools were construct valid. It appears that the learning aids were designed to support mathematical problem-solving concepts and skills. Every component of the multimedia-assisted E-LKPD complemented the learning objectives. Several variables made the learning tools valid. First, E-LKPD and lesson plans were content-valid. Content validity refers to how well learning aids meet curriculum criteria, notably the core competencies (KI) and basic competencies (KD) students must learn from the material. According to (Yuliyani, P., Sariningsih, R., Rohaeti, 2023), a learning tool is content-valid when it can measure learning objectives that match the lesson's content. Content validity is sometimes called curricular validity.

Second, the multimedia-assisted E-LKPD tool is built valid. This shows that the learning tool development was based on learning ideas and mathematical problem-solving indications. All components of the multimedia-assisted E-LKPD serve the learning objectives. The multimedia-assisted E-LKPD improved students' mathematical problem-solving and learning independence, according to the research. Pre-test and post-test, paired sample t-test statistical tests, N-Gain analysis, and student outcomes in Field Trial I and Field Trial II after learning tool upgrades show this effectiveness. (Nieveen, 2013) defines an effective learning tool as one that helps students meet learning objectives. This study aimed to promote students' mathematical problem-solving and learning independence. Multimedia-assisted E-LKPD improved both elements.

Learning independence is a student's ability to regulate learning, choose techniques, and assess results (Rustella, F., & Chotimah, 2023). Multimedia-assisted E-LKPD helped students learn independently in this study because they could understand the topic through multimedia presentations, follow the learning procedures, and complete assignments without relying on the teacher. Additionally, interactive learning activities encouraged students to participate in discussions, seek information, and solve problems. Multimedia makes E-LKPD learning more interesting and less monotonous. Images, animations, and interactive activities assist pupils in understanding abstract math. Multimedia-assisted learning can help students absorb material since it combines visual and linguistic elements, according to (Sumanik, N. B., & Siregar, 2023). The Field Trial II investigation found that the multimedia-assisted

E-LKPD was successful following upgrades. Multimedia-assisted E-LKPD can facilitate active, interactive, and student-centered mathematics learning.

D. Conclusion

The analysis and discussion conducted in accordance with the research objectives lead to the following conclusions: The validation results of the multimedia-assisted E-LKPD based on problem-based learning indicate that the developed tool meets the criteria of validity, practicality, and effectiveness. The use of multimedia-assisted E-LKPD based on problem-based learning improves mathematical problem-solving skills and indicates positive changes. Across all indicators of learning independence, multimedia-assisted E-LKPD based on problem-based learning clearly shows changes in students' learning independence. These changes are demonstrated by increased student initiative in learning, self-confidence in completing assignments, independence from others in completing exercises, and the ability to make decisions.

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