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Mathematics Learning Transformation through *MESSI LARI* Application: Critical Thinking Educative Game for Elementary Students

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Abstract: Mathematics Learning Transformation through *MESSI LARI* Application: Critical Thinking Educative Game for Primary School Students. Critical thinking skill is one of the essential 21st-century skills that plays a crucial role in addressing the complexity of life's problems. However, students still demonstrate low levels of critical thinking, as they tend to accept information without in-depth analysis. Elementary students are increasingly exposed to gadgets, often losing focus during lessons, relying on memorization rather than analyzing problems, and struggling to understand math questions. **Objective:** This study aimed to develop a technology-based learning medium to enhance students' critical thinking skills and to evaluate its validity, effectiveness, and practicality. **Method:** The Research and Development (R&D) approach was employed using the 4D model: Define, Design, Develop, and Disseminate. The study involved 27 fifth-grade students as subjects at Elementary School 4 Troso. The instruments included validation sheets, test items, and questionnaires. The data analysis used the paired sample t-test and the N-Gain test (to determine the effectiveness of the *MESSI LARI* application). **Findings:** First, the validation of the *MESSI LARI* application reached a mean score of 87% from two experts, classified as very valid. Second, the application reported an adequate effectiveness rate of 71.8% based on pretest and posttest results. Third, student questionnaire responses indicated a practicality score of 86.67%, categorized as very practical. **Conclusion:** This study confirms that the *MESSI LARI* application, a Critical Thinking Educational Game, is valid, effective, and practical for use in elementary mathematics learning.

Keywords: transformation, elementary mathematics, *MESSI LARI* application, educative game, critical thinking.

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INTRODUCTION

The advancement of technology has significantly influenced the field of education. Fricticarani (2023) explains that the rapid development of technology demands that students acquire more complex skills in the digital era. Digital transformation not only affects learning practices but also increases teacher engagement and enhances school performance across educational levels (Sayekti, Arief, & Utami, 2024). Particularly to align teaching practices with technological progress. The objective of transformational learning is to encourage individuals to think independently and to develop and expand their cognitive frameworks. (Patnaik, 2020).

At the elementary level, learning transformation plays a critical role in building

students' numeracy skills (Alsulami, 2025). Learning transformation signifies a substantial change in mindsets and methods applied in education, enabling approaches that align with reality and encouraging students to present knowledge reflectively and critically. Transformati ve learning, especially through digitalization and transformative teaching strategies, offers considerable potential to improve education quality (Jackson, 2008). One major challenge, however, lies in sustaining student engagement (Boussouf & Soualah, 2025). Mobile applications that use gamification concepts have proven effective in increasing student engagement (Samah, Ismail, & Hasan, 2022). In transformati ve learning, teachers serve as facilitators to support the learning process. By adapting to technological developments, this approach can help students grow and learn more effectively. Transformational learning changes how individuals view the world and contributes to improving the overall quality of education (Kumar, 2024).

Numeracy is a foundational skill students need to develop their academic competence. Numeracy skills refer to the ability to apply mathematical knowledge effectively and relevantly in various situations, including daily life, the workplace, and technology-supported environments (Adelia & Putri, 2024). Developing numeracy is a fundamental aspect of education that plays a crucial role in supporting lifelong learning and enhancing quality of life (Evans, 2017). Through numeracy, students can sharpen their skills in analyzing and interpreting data (Gantiyani, Cahya P, Atika S, & Hariati, 2022).

Given the importance of numeracy, teachers must be creative in designing interactive learning experiences. Anderson & Ludhra (2025) explain that to achieve learning goals, teachers need to apply various strategies and approaches aligned with students' diverse and engaging needs. Well-designed learning encourages students to participate more actively and interact during the learning process (El Sayad, Pannu, & Al Nakshabandi, 2023), which supports the achievement of educational goals. Interactive learning often uses role-play and simulations that replicate real-life conditions, allowing students to collaborate in problem-solving (Kopylova, 2022).

In addition to design effective learning, teachers can optimize technology utilization in teaching to improve learning quality (García, Méndez, & Chacón, 2023). Teachers' digital competence plays a key role in determining the quality of the education system and the success of digital technology integration in learning (Javorcik & Havlaskova, 2021). Teachers need training in the proper use of digital tools to maximize their benefits (Slade, Westerman, & Harrington, 2024). Proper use of technology can also enhance students' reasoning skills. Proper use of technology can also strengthen students' reasoning skills. The use of technology can increase students' interest, provide interactive learning experiences, and promote active engagement (Das & Malaviya, 2025).

Reasoning is a fundamental skill required to solve mathematical problems. Raj, Chauhan, Mehrotra, & Sharma (2022) explain that critical thinking is an essential skill for students because it helps them analyze, evaluate, and process information to make accurate decisions and solve problems effectively. Critical thinking is vital for addressing complex problems. They also noted that critical thinking supports the development of problem-solving skills. Students must have both critical and creative thinking skills, especially in learning mathematics. Students with critical thinking education achieved excellent academic outcomes and problem-solving skills (Sanchez-Lopez et al., 2025). In the context of mathematics, critical thinking includes processing information analytically, drawing evidence-based judgments, and solving problems through logical reasoning (Goos, 2020). Many mathematics teachers

recognize its importance, but they often face challenges in applying it, such as limited time and students' low concentration (Sukma, Diana, & Alfarisi, 2022).

Dwyer et al. (2014) described critical thinking as a metacognitive process, involving reflective judgment, that enables the provision of logical conclusions or solutions. In elementary schools, students are often presented with single-answer questions, which makes them less accustomed to facing complex situations. Educational games can highlight consequences and diverse perspectives, training students not only to memorize concepts but also to think reflectively and tackle complex problems. Critical thinking facilitates individuals to evaluate, interpret, and draw informed decisions (Verma, Devi, Bishnoi, & Jain, 2022). Azizah & Ibrahim (2019) explain three indicators of critical thinking: (1) the ability to break down information into parts, (2) the ability to evaluate credibility and relevance, and (3) the ability to draw conclusions based on available information. On the other hand, Tohiroh & Ariyanti (2024) identify four indicators of critical thinking: (1) the ability to interpret and explain the meaning of information, (2) the ability to clearly present the rationale for conclusions and decisions, (3) the ability to reflect on one's own thinking, and (4) the ability to draw conclusio ns. This skill fosters reflective and independent thinking, which is crucial for students to navigate complex challenges in today's technology-driven world (Watanabe & Schmohl, 2021).

According to the interview results, Mr. AF, a classroom teacher, stated that he had applied several learning models, including problem-based learning and STAD. However, they had not yet been effective in improving students' scores. They also frequently got exposed to gadgets and handphones, so their learning activities decreased. The preliminary research found that the students spent time memorizing instead of analyzing the problems. They also struggled with understanding mathematics questions, as evidenced by the 66.7% of students who were unable to reach the minimum mastery standard. They lacked confidence to share their arguments due to feeling afraid of making mistakes while expressing their ideas. Since students frequently use gadgets, the class had never used technology-based educational games in learning. Therefore, the *MESSI LARI* application became the first educational game students used in that class. This aligns with Zeng et al. (2020), who stated that educational games developed through scientific approaches enhance conceptual understanding and foster higher-order thinking skills, including critical thinking, across various learning settings.

Technological advancements bring significant changes in education, such as creative learning methods by utilizing animation and interactive media. Creative learning methods use innovative approaches that positively influence student learning outcomes by stimulating critical thinking, creativity, and learning motivation (Rahayuningsih, 2020). Therefore, teachers must develop their competencies, including using educational technology. This technology could be an effective mode to enrich learning, especially the numeracy skills. One example is the development of the "Parabolic Basketball VR" learning medium, a virtual reality game designed to improve students' understanding of projectile motion concepts in a more interactive and enjoyable way through basketball simulations (Villada Castillo, Bohorquez Santiago, & Martínez García, 2025).

The use of technology has created new opportunities for developing innovative and effective learning media. One example is the integration of technology-based media as a learning tool. Malik (2023) found that technology-based education positively affects student achievement, including academic performance, knowledge retention, and critical thinking skills. Media technology enables students to access

accurate information at any time and from anywhere (Aigul et al., 2022). These games can be tailored to specific learning objectives and adapted to individual learning styles, making them highly effective across diverse student groups (Lozano, Baldeon, Velarde, & Navarro, 2024). Research also shows that "Game-D" is an interactive learning game designed to enhance students' understanding of straight-line motion and robotics concepts engagingly by utilizing line-following robots (Eliza et al., 2025). This finding aligns with the results reported by Ibrahim et al. (2018), who found that 84% of respondents considered the game enjoyable and 80% agreed that it provided learning opportunities.

Application, an educational game, to foster critical thinking, especially learning transformation. This learning encourages students to solve problems rather than memorize the concepts. Thus, the material could also develop mathematical reasoning and critical thinking skills. Furthermore, Mengyao & Ismail (2025) also emphasized the importance of educational game design that gradually adjusts difficulty levels and presents varied elements to remain engaging and effectively support learning. The application engages and facilitates active participation of the students, and also stimulates logical thinking and mathematics critical thinking skills. Specifically, this study aims to (1) determine the feasibility of the developed application, (2) assess its effectiveness in improving students' critical thinking, and (3) analyze user responses.

METHOD

The method section of this study is organized systematically into four clearly separated parts: participants, research design and procedures, instruments, and data analysis.

Participants

This study took place at SD 4 Troso, Pecangaan District, Jepara Regency. The selection of SD 4 Troso as the research site was based on several considerations: (1) the school has implemented the Merdeka Curriculum, making it relevant to the study's focus on innovative learning media; (2) the student characteristics align with the research target, fifth graders in the concrete operational stage who learn material related to three-dimensional figures; and, (3) the school agreed to cooperate and granted official permission, which facilitated coordination with teachers and students. The research subjects included one expert lecturer for feasibility testing, one classroom teacher, and fifth-grade students. The study population consisted of all students at SD 4 Troso, with a sample of 27 students to evaluate the effectiveness of the developed *MESSI LARI* application. In addition, during the limited trial stage, 27 students evaluated the practicality of the application. For the large-scale trial, the sampling technique applied was saturated sampling, which involved all fifth-grade students.

Research Design and Procedures

This Research and Development (R&D) followed the 4D (Four-D) model developed by Thiagarajan, Semmel, and Semmel, consisting of four stages: define, design, develop, and disseminate (Rosa Yuliana, Muhamad Firdaus, & Dwi Oktaviana, 2022).

The research procedure consisted of four stages. First, in the define stage, the development requirements were identified and outlined based on field needs. In the design stage, the initial draft of the *MESSI LARI* application was created using information gathered during the define stage. Third, in the development stage, a revised and validated final draft was produced based on expert feedback. Fourth, in the dissemination stage, the validation and practicality of the approach were evaluated, and the final product was produced. |The steps of the 4D model are illustrated in Figure 1.

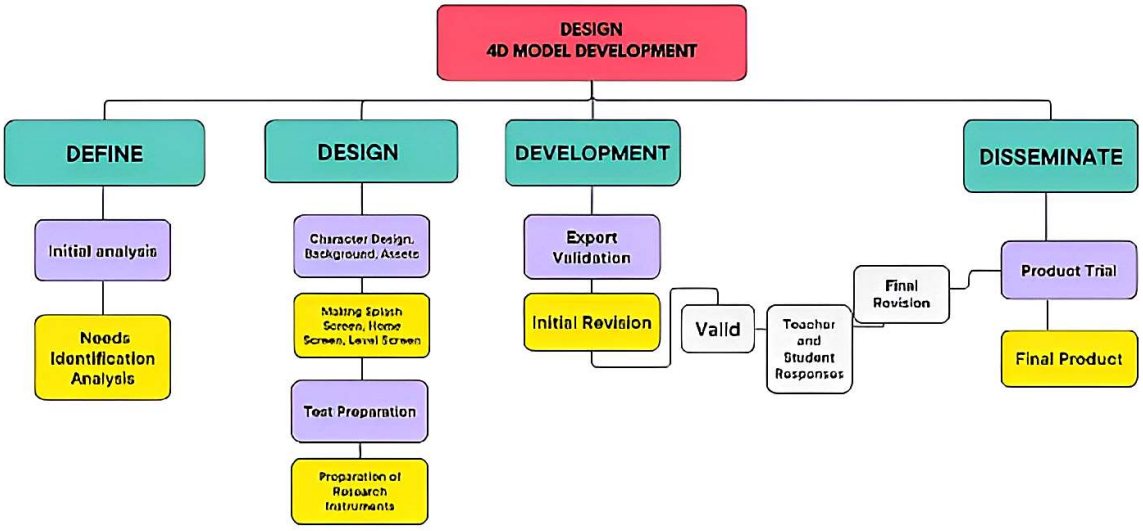


Figure 1. 4-D model design

Instruments

This study used non-test and test items as research instruments. The non-test instrument form questionnaire included validation sheets containing assessment items for each aspect appearance, content/material, learning, and programming which media experts completed. The response questionnaire included statements related to the use of the *MESSI LARI* application, completed by students.

The measurement of students' critical thinking improvement used pretest-posttest test instruments, developed based on Azizah & Ibrahim (2019). The indicators included: 1) the capability to elaborate information into some parts; 2) the capability to evaluate credibility and relevance; and the capability to draw a conclusion based on the given information. The test instrument measured students' knowledge of critical thinking skills and consisted of five multiple-choice questions at each level. In the application, students earn 20 points for each correct answer, while incorrect answers deduct 5 points from their score. At each level, students must achieve a minimum score of 75 to advance to the next level. The following is a sample test question categorized by critical thinking indicators.

Figure 2. Test items in the application

Figure 2 represents a question measuring the indicator of breaking down information into parts. To solve it, students must identify the three-dimensional shape (rectangular prism), determine the volume formula $V=p\times l\times t$, and calculate the full bottle volume (900 cm^3). Next, they analyze the condition: the remaining water equals half of the full volume. The final step requires a mathematical operation to determine the remaining volume (450 cm^3). This question supports the critical thinking indicator because students must analyze the problem by breaking down the information into structured parts, rather than merely memorizing formulas.

Data Analysis

The data from the expert validation questionnaire, using percentage scores of the

developed learning media, were then analyzed. Embringer et al. (2022) suggest determining validation criteria. The classification of validity is determined by the level of achievement obtained. An achievement level ranging from 85.01% to 100% is categorized as extremely valid. If the achievement level falls between 70.01% and 85.00%, it is considered valid. Meanwhile, an achievement level within 50.01% to 70.00% is regarded as less valid. Finally, when the achievement level is within the range of 01.00% to 50.00%, it is classified as invalid. After the product was validated, students' critical thinking skills were measured by analyzing their pretest and posttest scores using a normality test to verify the normal distribution of the population.

This study used the Shapiro-Wilk test for normality analysis because the sample size was fewer than 50. The rule states that if Sig is higher than 0.05, the data are assumed to follow a normal distribution; if Sig is less than 0.05, the data are not normally distributed. When the data are not normally distributed, nonparametric tests such as the Wilcoxon are applied. If the data were normally distributed, a paired sample t-test was used. This test assessed the effectiveness of the application's use. Table 2 presents the criteria for evaluating the effectiveness of the *MESSI LARI* application.

The effectiveness level was determined by the percentage achieved. A percentage of less than 40% is categorized as *ineffective*. If the percentage falls within the range of 40% to 55%, it is considered *less effective*. An achievement level between 56% and 75% is classified as *adequately effective*. Finally, when the percentage exceeds 76%, it is considered *effective* (Sukarelawan, 2024).

The improvement in student performance was measured using the N-gain score. Sukarelawan (2024) explains that N-gain is a commonly used method for evaluating instructional effectiveness. Table 3 presents the criteria for interpreting N-gain scores.

The N-Gain score criteria were used to classify the level of improvement achieved. An N-Gain score less than or equal to 0.3 is categorized as *low*. If the N-Gain score is greater than 0.3 but less than 0.7, it is classified as *moderate*. Meanwhile, an N-Gain score of 0.7 or higher is considered *high* (Febrianti, 2021).

The practicality data were obtained by analyzing the practicality questionnaire completed by fifth-grade students in percentage form. The results were interpreted based on the practicality criteria, adapted from Rahmansyah (2025). The practicality of the *MESSI LARI* application was assessed based on the percentage of achievement. A score ranging from 82% to 100% is interpreted as *very practical*. If the score falls within the range of 63% to 81%, it is considered *practical*. Meanwhile, a score in the range of 44% to 62% is classified as *less practical*. Finally, when the score lies between 25% and 43%, it is regarded as *impractical*.

■ RESULT AND DISCUSSION

This study successfully developed an educational game called the *MESSI LARI* Application to improve fifth-graders' critical thinking skills in geometry at Elementary School 4 Troso. The development process of the *MESSI LARI*: Mathematical Critical Thinking Educational Game is outlined below:

Defining Stage

In this stage, the core problem was identified that supports the development of the *MESSI LARI* application. This stage included two parts: initial analysis and needs identification. The initial analysis aimed to collect factual data and explore alternative solutions to the underlying problem, thereby facilitating the selection of the application to be developed. Based on this analysis, the development of *MESSI LARI* proved necessary, as the fifth-grade class at Elementary School 4 Troso lacked technology-based learning media and exhibited low critical thinking skills.

Therefore, the *MESSI LARI* application potential due to its engaging, fun, and interactive nature, enabling students to learn through play while improving their mathematical critical thinking skills.

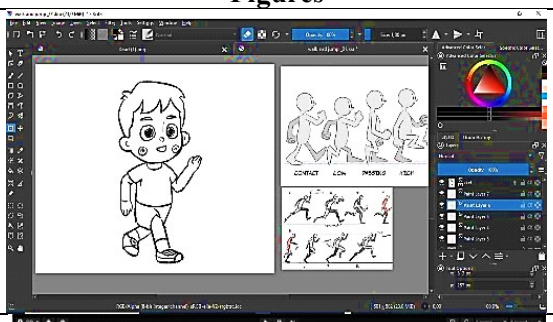
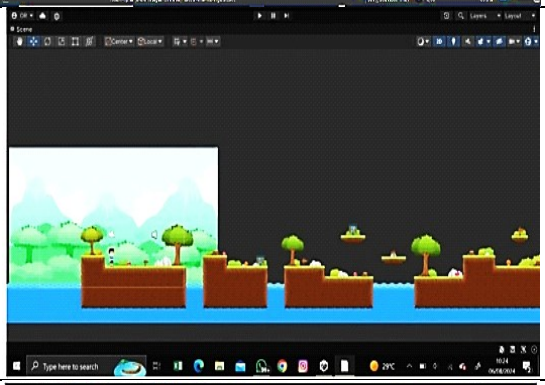
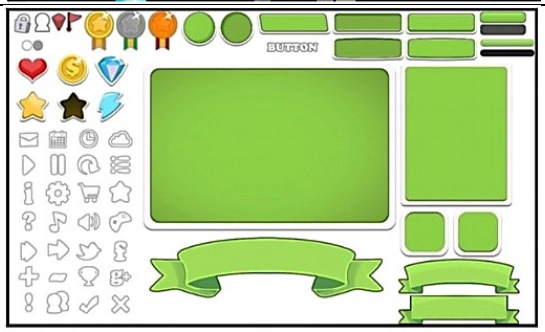
Designing Stage

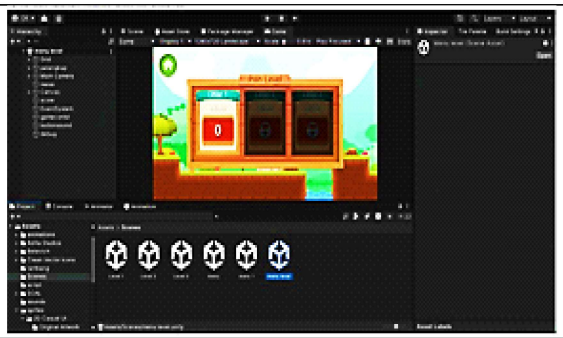
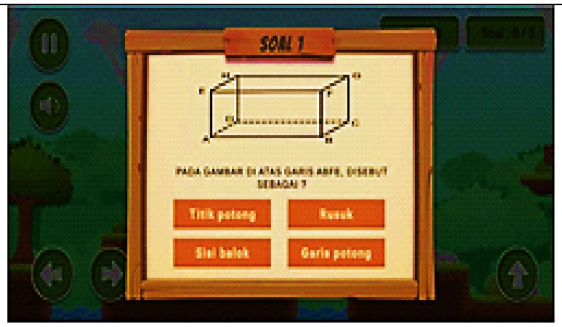
The initial product was developed by creating characters, backgrounds, and visual assets. The undertaken phase included designing the splash screen, home screen, and level screen. The phase also assembled test items and construct ed research instruments. The usability and feasibilit were ensured based on both available digital learning tools and previous research findings.

Visual components, including characters and background assets, were created, as well as user interface elements (such as the splash screen, home screen, and level screen). They carefully selected them to provide intuitive navigation and user engagement.

Following this, the assessment items were constructed and consisted of multiple-choice questions, five per level, designed to evaluate students' understanding within the game environment. Lastly, the instruments were created to measure the validity and effectiveness of the *MESSI LARI* application in improving students' mathematical critical thinking skills

Table 1. *MESSI LARI* application design

No	Figures	Explanations
1		The character of Messi was designed as an energetic boy who enjoys playing football.
2		The background in the *MESSI LARI* application reflects the atmosphere typical of elementary school students.
3		Various interface assets, including buttons and panels, were created to enhance the application's visual display.

4		The splash screen features the game's logo alongside an image of Messi and appears when the game launches.
5		The home screen presents several main menu options and game settings.
6		The level screen features selectable level menus, enabling players to select the stage they wish to play.
7		Test items were also developed within the application. As players progress, they must overcome various challenges by answering questions integrated into the game.

Development Stage

The development stage aimed to revise and refine the *MESSI LARI* application through evaluation and revision before finalizing it as a valid product. In this study, the development process included the following steps: First, expert validation. Two validators assessed the application's validity. The first validator, a lecturer in primary teacher education with expertise in educational technology, and the second, a classroom teacher, evaluated the application and research instruments. Both provided assessments and suggestions for improvements. Table 2 presents the results of their evaluations.

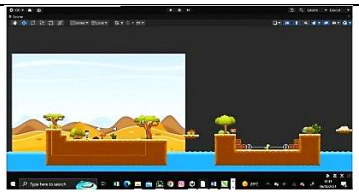
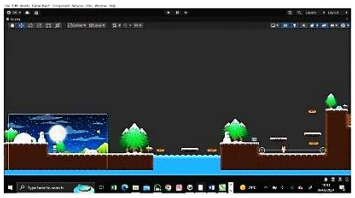
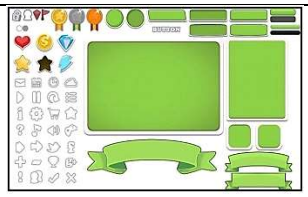
The media validation encompassed five aspects and comprised a total of 27 statements, all of which were categorized as valid. However, the validators provided several suggestions,

Table 2. Validity results of media experts

Aspects	Validators		Average	Criteria
	1	2		
Application design	85%	87%	86%	Extremely valid
Application display	90%	86%	88%	Extremely valid
Benefits	88%	90%	89%	Extremely valid
Language use	85%	85%	85%	Extremely valid
Content component	86%	88%	87%	Extremely valid
Average	**86,8%**	**87,2%**	**87%**	**Extremely valid**

comments, and recommendations for improving the *MESSI LARI* application. These revisions served to refine the product, ensuring that *MESSI LARI* would be ready for use in research aimed at enhancing students' critical mathematical reasoning skills. The updated product specificatio also allow for broader implementation. The revisions are outlined as follows:

Table 3. Revised media

No	Before revision	After revision	Explanations
1			The validator recommended giving the main character a distinctive feature. In response, the "M" logo, located to the upper left of Messi's shirt, was added, representing the character's identity in the application.
2		 Level 2  Level 3	For the background, the validator suggested using a different background for each level. The revision: Level 1 features a mountain landscape with trees, Level 2 adopts a desert theme, and Level 3 uses a snowy night setting.
3			Regarding asset design, the enemies were added to the game. Levels 2 and 3 now include obstacles that players must overcome. Level 2 features a dinosaur enemy, while Level 3 includes a cat enemy.
4			Before displaying the home screen, a brief introduction was added featuring the character Messi, who can speak and move his hands.

After validating and revising the *MESSI LARI* application, a limited trial was conducted at Elementary School 4 Troso Jepara. This trial aimed to assess the effectiveness and improvement of the application. To evaluate effectiveness, the students' pretest and posttest scores were compared at each level of the application.

The normality test was carried out using both the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results of the Kolmogorov-Smirnov test show a significance value of 0.027 for both the pretest and the posttest, which are both less than 0.05. According to the Kolmogorov-Smirnov test, the data are not normally distributed. However, the Shapiro-Wilk test yields significance values of 0.080 for the pretest and 0.063 for the posttest, both of which are greater than 0.05. Therefore, based on the Shapiro-Wilk test which is generally considered more reliable for small sample sizes ($n < 50$) the data can be considered normally distributed. Students' critical thinking achievement was measured through pretests and posttests. This study used the Shapiro-Wilk method to test normality because the sample was fewer than 50. Indicates a significance value > 0.05, indicating that the data were normally distributed. The t-test identified significant differences between pretest and posttest scores. The results appear in Table 4.

Table 4. Paired sample T-Test results

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	pretest - posttest	-35.88889	15.49028	2.98111	-42.01664	-29.76114	-12.039	26	.000

The results of the paired sample t-test showed a significance value of 0.000, indicating a statistically significant difference between the results before and after using the *MESSI LARI* application. Nuryadi (2017) explains that if the Sig (2-tailed) value is <0.005, then Ha is accepted and Ho is rejected.

The N-Gain test was conducted to measure learning improvement during the limited trial with fifth-graders at Elementary School 4 Troso Jepara. The application included 15 multiple-choice questions, with five questions assigned to each level.

Level 1 tested knowledge of the characteristics of cubes and rectangular prisms, level 2 covere d the volume of cubes, and level 3 focused on the volume of rectangular prisms.

Table 5. N-Gain test results

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
ngain_score	27	.44	1.00	.7182	.18005
ngain_persen	27	44.44	100.00	71.8227	18.00548
Valid N (listwise)	27				

Table 5 indicates an N-Gain score of 0.71, corresponding to a 71.8% increase, and is categorized as a high-level improvement. Figure 3 presents the critical thinking skill improvements based on the indicators of Azizah & Ibrahim (2019)

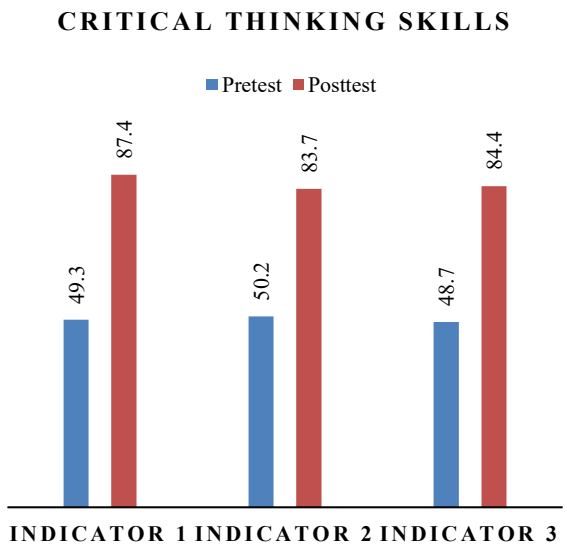


Figure 3. Students' critical thinking skill improvements for each indicator

The results show improvements across all three indicators between the pretest and posttest. Indicator 1 (the ability to break down information into parts) increased because the educational game presented problems interactively and contextually. This approach encouraged students to separate relevant data, analyze solution steps systematically, and interpret relationships among pieces of information before making decisions. This finding aligns with Dwyer et al. (2014), who argue that reflective judgment develops when individuals are trained to identify problem components and weigh the relationships among information before making a decision.

Indicator 2 (the ability to evaluate credibility and relevance) improved because the educational game on cube and cuboid volume exposed students to varied information and answer choices that required them to distinguish accurate, relevant, and reliable data. This process trained students not only to accept information directly but also to assess the accuracy of concepts, the suitability of formulas, and the correctness of their application in given problems, thereby fostering more directed critical thinking.

Indicator 3 (the ability to draw conclusions based on available information) also improved because the educational game on cube and cuboid volume trained students to connect data from problems and game simulations with relevant mathematical concepts. In this process, students organized information, identified patterns, and linked calculation results to construct logical and accurate conclusions. Thus, the educational game encouraged students not only to calculate but also to formulate final answers as evidence of a more profound understanding of cube and cuboid volume concepts.

Disseminate Stage

The dissemination stage marked the final phase of the Thiagarajan development model. During this phase, a product trial was conducted to assess its practicality before finalization.

To measure practicality, the student response questionnaire using the Guttman scale was distributed to fifth-grade students at Elementary School 4 Troso. The results are presented in Table 6.

Based on the student response questionnaire in Table 6, the average practicality level of the media reached 86.67%, indicating a highly practical approach. The score of 86.67% was obtained by summing the 10 aspects in Table 11 and dividing by the total number of aspects. Since Aspect 5 was a negative statement, the adjusted value used was 78%. Aspect 1 received a score of 100% because students at SD 4 Troso felt motivated in learning, as the *MESSI LARI* application was the first educational game used in fifth grade. This finding aligns with Ibrahim et al. (2018), who reported that about 80% of students showed positive attitudes toward

Table 6. Results of student response questionnaire

No	Aspects	Results
1	Feeling joyful while learning with a game	100%
2	The game makes learning more attractive.	100%
3	The game facilitates understanding the lesson easily.	93%
4	The game encourages students' spirits.	85%
5	Game lessens students' boredom.	22%
6	Students love the high frequency of using games in learning.	96%
7	The game facilitates students to work on questions better.	93%
8	Students could learn while playing a game.	81%
9	Students want to use the game in other lessons.	74%
10	Learning with a game is more joyful than conventional learning.	67%
	Average	**86.67%**

educational games, with 84% finding them enjoyable and 80% agreeing that the games provided learning opportunities. In aspect 5, "the game makes students feel bored quickly," the result was 22% a negative statement indicating that over 70% of students did not feel bored during learning with the game. Some students felt bored because it was their first time using a technology-based educational game, which made it difficult for them to operate, resulting in frequent repetition during play. This finding also supports Mengyao & Ismail (2025) and Keller's ARCS Model of Motivation, which emphasizes the importance of attention and relevance. Suppose a game fails to sustain attention through variety or lacks relevance to students' needs, intrinsic motivation to learn decreases. Thus, students' feelings of boredom highlight the importance of educational game design that gradually adjusts difficulty levels and incorporates varied elements to remain engaging and effectively support learning.

After product testing and revisions during the development phase, the *MESSI LARI* application proved to be highly feasible and practical. During the dissemination stage, the research team planned to introduce the *MESSI LARI* application to other elementary schools in Jepara and Kudus Regencies.

The *MESSI LARI* application, an educational game designed to enhance mathematical critical thinking, was developed using the 4D model. The define phase aimed to identify the core problems that supported the application's development. During the design phase, the team created a product tailored to meet real classroom needs. The development phase involved refining the *MESSI LARI* application through evaluation and revision before finalizing the product. In the dissemination phase, the application's practicality was evaluated and prepared for broader implementation across elementary schools.

According to Kurniawan, as cited by Hodiyanto et al. (2020), educational research should not only produce a product but also ensure the quality of that product through several tests, including validity, practicality, and effectiveness. When a product meets these standards, it can serve as an effective learning medium, enhancing students' critical thinking skills and enabling their application in broader contexts. In this research, the final product was the Android-based *MESSI LARI* application.

This educational math game was validated by media experts. Two validators participated: a university lecturer in PGSD with expertise in

educational technology and a 4th-grade elementary school teacher from Elementary School 4 Troso. The media validation score reached 87%, which is classified as highly valid. The high score resulted from revisions based on validator feedback, as shown in Table 7. One significant revision was adding the "M" logo to the main character. This element improved the application's design by providing a strong visual identity, helping students recognize the character, and enhancing the game's aesthetic appeal. Validators also appreciated the background variations at each level. Gradual changes in background reduced monotony and increased student engagement, supporting the usefulness aspect, particularly in maintaining learning motivation. The visual variety encouraged students to continue playing while learning three-dimensional concepts. Another revision involved adding enemies such as dinosaurs and cats, which created a more challenging gameplay experience. Validators noted that this addition enhanced the design by introducing interaction dynamics and improved its usefulness by fostering persistence, strategy, and concentration. Together, these revisions contributed significantly to the high validity, as the game was not only visually appealing but also effective in supporting learning objectives. Based on these results, the *MESSI LARI* application was deemed a suitable tool for transforming mathematics learning and improving students' critical thinking skills. Masduki et al. (2020) also found that educational games positively impact children's intelligence, especially in cognitive development closely related to critical thinking and problem-solving.

After completing media validation, it proceeded to the product testing stage. This stage aimed to assess the practicality and effectiveness of the educational math game. The results indicated that the *MESSI LARI* application was effective, as evidenced by a significance value of <0.005 and an N-Gain score of 0.8, which falls into the high improvement category.

To measure practicality, the average student response reached 86.67%, categorized as highly practical. The effectiveness was assessed using the post-test results from the trial phase. Among the participants, 21 students achieved mastery, while six did not, as their scores fell below the minimum mastery standard set by KKTP. Overall, the application achieved an adequately effectiveness rating of 71,8%, indicating that *MESSI LARI* effectively enhanced students' mathematical critical thinking on 3D shapes in fifth graders. One example of a game feature that strengthens critical thinking indicators is the progressive level system. Students must correctly solve each level to advance, which requires them to calculate volume accurately and draw conclusi ons. This mechanism trains students to construct logical arguments based on problem data to reach the correct answer. It directly supports the indicator of breaking down information into parts, as noted by Azizah & Ibrahim (2019).

Critical thinking in mathematics involves the ability to evaluate information logically, make judgments based on evidence, and solve problems through analytical approaches. Similarly, Bezanilla et al. (2023) stressed that a profound understanding of critical thinking both from students' and educators' perspectives forms the foundation of meaningful learning processes that aim to develop high-level cognitive skills. The practical implication for students is that engaging in interactive and challenging learning activities can help develop critical thinking skills. For future researchers, the findings provide a reference that highlights the importance of design aspects such as visuals, variation, and challenge in making media more effective and engaging. The theoretical implication confirms that educational games can develop critical thinking indicators.

Research Limitations

This study was limited by a relatively small sample size drawn from only one school, so the findings cannot yet be widely generalized.

Therefore, further research should involve larger samples with diverse geographic and socioeconomic backgrounds to produce more representative results and stronger external validity. This limitation also presents opportunities for future researchers to expand similar studies into broader contexts, thereby providing more significant contributions to the development of game-based learning media.

■ CONCLUSION

This study successfully developed the *MESSI LARI* application (Critical Thinking Educational Game), which proved to be valid, practical, and effective in enhancing the mathematical critical thinking skills of 5th-grade students at Elementary School 4 Troso. In terms of learning media innovation, the author developed a geometry educational game (cube and cuboid) that is not only enjoyable but also integrated with critical thinking indicators, enriching interactive learning media alternatives in elementary schools. Strengthening the educational design aspect shows that expert-based revisions (adding character logos, background variations, and enemies) significantly improved the media's design quality and usefulness, providing important evidence for research and development (R&D) practices in education. The research followed four stages: define, design, development, and disseminate. The results indicated that the application achieved a high level of validity in delivering the 3D shapes material for 5th-grade students. It also demonstrated effectiveness in supporting students' understanding of the topic. Furthermore, the application was rated as highly practical, confirming its suitability for classroom use and ease of implementation in elementary mathematics learning.

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