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Enhancing Logical Thinking Skills Through Structured Inquiry Learning Assisted By Game-Based Interactive Multimedia

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ABSTRACT

Logical thinking is a fundamental skill required for effective problem solving and decision making; however, conventional instruction often provides limited opportunities to develop this ability. This study aims to examine the effectiveness of Structured Inquiry Learning supported by game-based interactive multimedia in improving students' logical thinking skills. A research and development approach was employed, followed by a one-group pretest–posttest design involving 28 vocational high school students at SMK Negeri 1 Cimahi. Students' logical thinking skills were measured using validated multiple-choice instruments, and data were analyzed using N-gain analysis, Shapiro–Wilk normality testing, and the Wilcoxon Signed-Rank test. The results demonstrate a significant improvement in students' logical thinking skills after the intervention, with moderate N-gain scores observed in logical sequencing and conclusion-drawing indicators, while argumentation skills showed a lower gain. Students also reported highly positive perceptions of the developed multimedia in terms of usability, content quality, and multimedia elements. These findings indicate that integrating game-based interactive multimedia within a Structured Inquiry Learning framework effectively supports logical thinking development by promoting active inquiry, engagement, and reflective learning, suggesting its potential application in vocational secondary education contexts.

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1. INTRODUCTION

The quality of education in Indonesia continues to face systemic challenges, particularly in students' learning outcomes and higher-order thinking skills. International assessments such as the Programme for International Student Assessment (PISA) 2022 indicate that although some improvements have been observed, Indonesia's performance in literacy, mathematics, and science remains below the average of many participating countries. This condition reflects persistent difficulties in developing essential 21st-century competencies, including problem-solving, critical thinking, and logical thinking (OECD Indonesia, 2023). National reports on PISA further emphasize the need for post-pandemic learning recovery and the improvement of instructional practices that actively stimulate higher-order thinking skills (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2023).

Logical thinking is a fundamental cognitive skill that enables individuals to analyze information accurately, evaluate arguments, and draw valid conclusions, particularly in the context of increasing information complexity in the digital era (Octaria, 2017; Voogt & Roblin, 2012). Previous studies have highlighted that logical thinking is essential for solving complex problems and making sound decisions (Sezen & Bülbül, 2011). In science learning, logical thinking also serves as an indicator of students' scientific reasoning abilities and plays a critical role in supporting conceptual understanding (Ramirez et al., 2019).

Despite its importance, current instructional practices often remain focused on memorization and content transmission, with limited opportunities for students to actively engage in reasoning processes. Such approaches may neglect the development of logical thinking skills, resulting in low conceptual understanding and difficulties in applying knowledge to real-life problem situations (Fitria & Malik, 2022). Empirical evidence shows that students, including those at the tertiary level, continue to experience difficulties in solving tasks that require logical reasoning in science-related subjects (Marta et al., 2020; Aminudin et al., 2019).

One contributing factor to this issue is the dominant use of static instructional media, such as PowerPoint presentations, which tend to promote one-way communication and limit student interaction (Tarigan & Siagian, 2015). This practice contradicts the fundamental concept of learning as an interactive process between students, teachers, and learning resources within a learning environment (Chatib, 2009). The use of multimedia in learning has been shown to facilitate interaction, support individualized learning, integrate audiovisual elements, and provide immediate feedback, thereby creating a more continuous and meaningful learning process (Miftah, 2018). Studies have reported that interactive multimedia leads to higher learning gains compared to conventional instruction, as reflected in improved learning outcomes and normalized gain scores (Radityan et al., 2016).

Interactive multimedia offers several advantages, including ease of operation, learner control over content selection, and systematic learning navigation (Munir, 2008). Learning media can also clarify the presentation of information and enhance both learning processes and outcomes (Arsyad, 2002). Empirical studies consistently indicate that interactive multimedia is more effective than traditional text-based materials in improving students' motivation and learning outcomes (Armansyah et al., 2019; Nusir et al., 2013). Furthermore, educational games, as a form of interactive multimedia, integrate visual, auditory, and interactive elements that engage learners in problem-solving and cognitively demanding tasks, making learning more engaging and less monotonous (Saputri et al., 2018).

To support meaningful learning, instructional approaches that emphasize active exploration and reasoning are required. Inquiry-based learning, particularly the Structured Inquiry Learning model, actively involves students in analyzing problems, formulating

hypotheses, conducting investigations, and drawing conclusions through a guided and systematic process (Jerrim et al., 2022). Research has shown that inappropriate instructional methods can hinder the development of students' logical thinking skills, whereas inquiry-oriented approaches provide opportunities for students to focus on reasoning processes rather than merely learning outcomes (Nugraha & Mahmudi, 2015; Sari & Hoiriyah, 2020).

Based on these considerations, integrating Structured Inquiry Learning with game-based interactive multimedia presents a promising approach to addressing limitations in current instructional practices. However, research that explicitly aligns game mechanics with structured inquiry stages and examines their impact on students' logical thinking skills remains limited, particularly in vocational secondary education contexts. Therefore, this study aims to enhance students' logical thinking skills through the implementation of Structured Inquiry Learning assisted by game-based interactive multimedia.

2. METHODS

2.1. Research design

This study employed a research and development (R&D) approach to develop and implement game-based interactive multimedia integrated with the Structured Inquiry Learning model. The development process was conducted using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. This model was selected because it provides a systematic and iterative framework for developing instructional products that are aligned with learning objectives and learner needs.

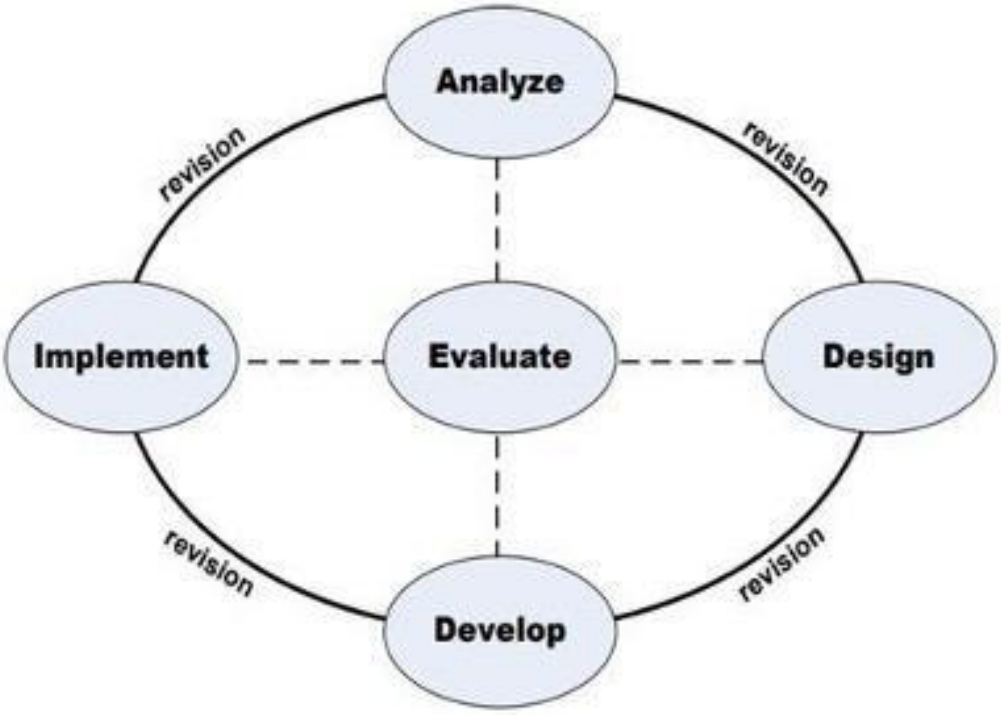

Figure 1. The ADDIE development model

to examine the effectiveness of the developed multimedia, a pre-experimental design using a one-group pretest–posttest approach was applied. This design was used to identify changes in students' logical thinking skills before and after the learning intervention.

Table 1. One group pre-test and post-test

Notation:
O1 = Conditions before the treatment
X = Treatment
O2 = Condition after the treatment

2.2. Participants

The participants of this study were 28 eleventh-grade students from the Software and Network Engineering (Sistem Informasi Jaringan dan Aplikasi) program at a vocational high school in Cimahi, Indonesia. The selection of participants was based on the availability of one intact class and the relevance of the learning material to the students' field of study. The learning intervention was conducted during regular instructional sessions, with students engaging in the game-based interactive multimedia independently using personal computers.

2.3. Development of game-based interactive multimedia

The game-based interactive multimedia was developed to support the stages of Structured Inquiry Learning, including orientation, conceptualization, investigation, conclusion, and discussion. The multimedia integrated interactive challenges, problem-solving tasks, and immediate feedback mechanisms to guide students through each inquiry stage. The game design incorporated essential multimedia elements such as visuals, audio, animations, and user interaction to create an engaging learning environment (Arsyad, 2002).

The instructional content and game mechanics were designed to encourage logical reasoning, hypothesis testing, and evidence-based conclusion drawing. The use of interactive multimedia as a learning medium was intended to facilitate active learning, learner control, and meaningful engagement, which have been shown to support improved learning outcomes (Miftah, 2018; Armansyah et al., 2019).

2.4. Instruments

Data were collected using three main instruments: logical thinking tests, expert validation sheets, and student response questionnaires. The logical thinking test was administered as a pretest and posttest to measure changes in students' logical thinking skills after the learning intervention. The indicators assessed included reasoning coherence, argumentation ability, and conclusion-drawing skills, which are commonly associated with logical thinking in science learning contexts (Octaria, 2017; Ramirez et al., 2019).

Expert validation sheets were used to assess the feasibility of the developed multimedia in terms of mechanics, multimedia elements, information structure, documentation, and content quality. In addition, student response questionnaires were administered to gather students' perceptions of the usability and effectiveness of the multimedia during the learning process.

2.5. Data analysis

The collected data were analyzed descriptively and quantitatively. Pretest and posttest scores were compared to determine improvements in students' logical thinking skills. The magnitude of improvement was calculated using normalized gain (N-Gain) analysis to evaluate the effectiveness of the learning intervention. Student response data were analyzed using percentage scores to determine the overall quality and feasibility of the developed multimedia.

3. RESULTS AND DISCUSSION

The implementation of game-based interactive multimedia integrated with the Structured Inquiry Learning model produced measurable improvements in students' logical thinking abilities. These improvements were evident from both descriptive and inferential statistical analyses, as well as from students' responses toward the multimedia used during the learning process.

Based on the descriptive analysis, the average total score of students' logical thinking increased from 61.2 in the pretest to 81.2 in the posttest, indicating a substantial improvement after the treatment. This finding suggests that the learning activities supported by interactive multimedia were able to facilitate students' engagement in inquiry processes, such as organizing ideas, formulating arguments, and drawing conclusions. The improvement aligns with the premise that inquiry-oriented learning environments, when supported by interactive digital media, can promote higher-order thinking skills (Miftah, 2018).

Further analysis using the N-gain test shows differentiated improvements across indicators of logical thinking. Students' coherence of thinking improved with an N-gain of 0.5 (moderate category), while argumentation ability showed a lower improvement with an N-gain of 0.3 (low category). In contrast, the ability to draw conclusions achieved the highest improvement with an N-gain of 0.6 (moderate category).

Table 2. N-Gain results for each logical thinking indicator

Logical Thinking Indicators	***Pretest***	***Posttest***	***Gain***	**Category**
Logical sequencing	60,7	82,1	0,5	Moderate
Argumentation ability	69	79,8	0,3	Low
Drawing conclusion	54	81,7	0,6	Moderate

These results indicate that the multimedia-supported inquiry activities were particularly effective in helping students synthesize information and formulate conclusions. This may be attributed to the structure of the game-based multimedia, which required students to complete investigation tasks and receive immediate feedback before proceeding to the conclusion stage. Such features are consistent with the principles of learner control and feedback emphasized in interactive multimedia learning (Arsyad, 2002; Armansyah et al., 2019).

However, the relatively lower improvement in argumentation ability suggests that students still faced challenges in articulating and defending their reasoning. Although the multimedia provided problem-solving scenarios, opportunities for explicit argumentative dialogue such as comparing alternative answers or justifying choices verbally may have been limited. This finding is consistent with previous studies indicating that argumentation skills require sustained scaffolding and social interaction beyond individual task completion (Miftah, 2018).

Inferential statistical analysis further supports the effectiveness of the intervention. The Shapiro–Wilk normality test showed that pretest scores were normally distributed, while posttest scores were not, leading to the use of the Wilcoxon Signed Ranks Test. The results of the Wilcoxon test indicate a significant difference between pretest and posttest scores, confirming that the observed improvement in logical thinking was not due to chance.

Table 3. Wilcoxon Signed Ranks test results

		N	Mean Rank	Sum of Ranks
Posttest - PreTest	Negative Ranks	2[a]	14.00	28.00
	Positive Ranks	26[b]	14.54	378.00
	Ties	0[c]		
	Total	28		

a. Posttest < PreTest
b. Posttest > PreTest
c. Posttest = PreTest

Test Statistics[a]

Posttest - PreTest

Z	-3.988[b]
Asymp. Sig. (2-tailed)	<.001

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

From a pedagogical perspective, these findings reinforce the role of game-based interactive multimedia as an effective learning medium when aligned with inquiry-based instructional models. The multimedia developed in this study incorporated visual elements, animations, interactive challenges, and feedback mechanisms that guided students through the stages of Structured Inquiry Learning. These design features likely reduced cognitive load and helped students focus on reasoning processes rather than procedural difficulties.

The effectiveness of the multimedia is further supported by students' responses toward its use. Analysis of students' feedback indicates a very positive response across aspects such as usability, attractiveness, clarity of information, and content qualit

Table 4. Student response analysis toward multimedia

Aspect	Items	Ideal Score	Score	(%)
Mechanism	4	100	86	86
Multimedia Element	2	50	50	100
Information Structure	2	100	98	98
Documentation	2	50	47	94
Content Quality	5	325	315	97

Students reported that the game mechanics and interactive elements made learning more engaging and helped them understand the material more easily. This positive perception is important, as learner engagement and motivation are known to mediate the impact of multimedia on learning outcomes (Miftah, 2018; Armansyah et al., 2019). The combination of inquiry-based tasks and game elements appears to have encouraged active participation, which in turn contributed to improvements in logical thinking skills.

Nevertheless, the absence of data related to long-term retention or comparative effectiveness against non-multimedia inquiry learning limits the generalization of these findings. Additionally, while the multimedia was effective in supporting individual reasoning processes, future designs may need to integrate collaborative or discussion-based features to better foster students' argumentation skills.

Overall, the results demonstrate that game-based interactive multimedia, when systematically designed to support Structured Inquiry Learning, can significantly enhance students' logical thinking abilities. The integration of interactive features, inquiry stages, and immediate feedback plays a crucial role in facilitating meaningful learning experiences, particularly in supporting students' ability to organize reasoning and draw conclusions.

4. CONCLUSION

This study demonstrates that the implementation of Structured Inquiry Learning assisted by game-based interactive multimedia has a positive and statistically significant effect on students' logical thinking skills. The findings indicate a meaningful increase in overall logical thinking performance, as reflected in the improvement of posttest scores compared to pretest results and supported by non-parametric statistical analysis. Moderate N-gain values observed in indicators of logical sequencing and conclusion drawing suggest that the inquiry-oriented game environment effectively facilitated students' reasoning processes, while lower gains in argumentation indicate the need for further instructional reinforcement in this aspect.

The integration of game-based interactive multimedia played a crucial role in supporting the inquiry process by providing interactive challenges, immediate feedback, and problem-solving tasks aligned with each stage of Structured Inquiry Learning. Students' positive

responses toward the multimedia, particularly regarding usability, content quality, and multimedia elements, indicate that the developed game created an engaging and supportive learning environment that encouraged active participation and independent exploration.

Despite these promising results, this study was limited by the use of a single-group pretest–posttest design and a relatively short intervention duration. Future studies are recommended to employ comparative experimental designs, longer implementation periods, and more detailed analyses of specific multimedia features to further examine their impact on different dimensions of logical thinking. Overall, the findings suggest that Structured Inquiry Learning supported by game-based interactive multimedia is a viable and effective approach for enhancing logical thinking skills in vocational secondary education.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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