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Optimization of Digital Game Media in Game-Based Learning to Enhance Critical Thinking Skills in Science Learning

Sinta Yuni Fitanti[1*], Binar Kurnia Prahani[1], Suryanti[1], Hanandita Veda Saphira[2]
[1] State University of Surabaya, Surabaya, Indonesia
[2] University of Wollongong, Wollongong, Australia

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ABSTRACT

Objective: *This study has the objective to analyze the implementation of a game-based learning model in improving the critical thinking skills of elementary school students in learning science material on energy sources, focusing on the implementation of learning, the effectiveness of improving critical thinking skills, and student responses.* ***Method:*** *The research method used is quantitative with an experimental design of control group pretest posttest design involving 90 fourth grade students who are divided into three groups: experiment 1 using the digital game "Science Detective", experiment 2 using the board game "Energy Expedition", and the control group with conventional learning. The research instruments included an implementation observation sheet, critical thinking skills test, and learner response questionnaire, with data analyzed using t-test and N-gain calculation.* ***Results:*** *The results showed that the game-based learning model achieved a 96% implementation rate with a very good category. The N-gain in experimental group 1 with high category, experiment 2 with high category, while the control group with medium category. The "Science Detective" game showed consistent improvement in all critical thinking indicators including interpretation, analysis, inference, and evaluation. Learners' responses were very positive.* ***Novelty:*** *The novelty of this research lies in the comprehensive integration of the analysis of implementation, effectiveness, and learner responses to the implementation of game-based learning in the context of elementary school science learning, by developing two different game media for comparison of effectiveness in improving critical thinking skills.*

INTRODUCTION

The transformation of education in the era of society 5.0 demands a learning paradigm that is no longer centered on the transfer of knowledge alone, but on the development of skills that are relevant to the demands of modern times. Ki Hajar Dewantara's educational philosophy that emphasizes the development of talents, interests, and potential of students to achieve optimal happiness as humans and members of society is becoming increasingly relevant in the context of contemporary education (Sulistyaningrum et al., 2023). The rapid development of information and communication technology has fundamentally changed the educational landscape, where learners are required to have critical thinking skills as a provision to face the complexity of information and problems in the future. Critical thinking skills are one of the core competencies that must be developed in 21st century learning (Taib, 2021). Critical thinking skills are the ability to analyze, evaluate, and draw conclusions from information through a logical and systematic thinking process to solve problems. This ability helps learners make rational decisions and improve their understanding of various phenomena around them (Prahani et al., 2023).

In the context of science learning, critical thinking skills are very important because they enable learners to relate theoretical knowledge to everyday events, analyze empirical data, and develop a deep understanding of scientific concepts (Ana &

Muksodah, 2024). The implementation of an independent curriculum that aims to encourage learners to actively participate in education and become independent individuals emphasizes the importance of developing critical thinking skills (Putri, 2024). Science learning in this curriculum framework does not only require students to memorize scientific concepts, but also involves the development of scientific attitudes, scientific process skills, and the ability to produce scientific products that can be applied in real life. Science learning demands the development of the ability to connect abstract concepts with empirical data collection, which requires good critical thinking skills from students (Kusmiati et al., 2019).

However, the reality in the field shows an alarming phenomenon related to the low critical thinking skills of elementary school students. Preliminary studies conducted at Elementary Scholl of Tanggul on grade IV students showed that out of 40 students, 20 students or 50% were categorized as having low critical thinking skills, followed by 10 students or 25% in the medium category, 4 students or 10% in the very low category. In contrast, only 3 learners or 7.5% showed very high critical thinking skills and 3 other learners or 7.5% in the high category (Fitanti & Prahani, 2024). This finding is in line with other research that shows the low critical thinking skills of elementary school students in Indonesia, with the results showing 66.7% of elementary school students have moderate critical thinking skills, and in general the critical thinking skills of students in science learning in Indonesia are still in the low to moderate category (Azizah et al., 2021). The main factor that causes low critical thinking skills is the dominance of the use of conventional learning models that are still teacher-centered (Indrianto, 2024). Observations show that some teachers have not fully succeeded in creating an active learning environment that favors students. The dominance of the lecture method, the lack of practicum activities, and the lack of connection of material with real life make students less involved in the learning process and have difficulty understanding concepts in depth. As a result, students' potential in developing critical thinking skills has not been optimized. Variations in learning models can improve learners' critical thinking skills, and teachers can adopt a constructivism approach to facilitate more active and meaningful learning (Sucipta et al., 2023).

The development of digital technology opens opportunities for innovation in learning through a game-based learning approach. This innovative learning model uses games as a tool to achieve learning objectives by making learning more interesting and interactive, so that it can increase learning motivation, concept understanding, and student learning outcomes (Lintangesukmanjaya et al., 2025). Research shows that game-based learning can improve learners' ability to think critically, as they become more skillful in evaluating information, weighing options and making informed decisions. Game-based learning trains important 21st century skills such as collaboration, communication, creativity and critical thinking, where learners learn to work together in teams, communicate their ideas and find innovative solutions (Ananda & Agusta, 2023). A number of previous studies have proven the potential of game-based learning in transforming learning, but there are still gaps that need to be bridged. Wahyuning (2022) emphasized the urgency of using game-based learning in science learning due to the characteristics of this subject which is full of abstract concepts and difficult to understand.

The game-based learning is able to create an interactive learning atmosphere through a learning by doing approach, so that learning becomes more contextual, meaningful, and fun (Kristina et al., 2025). The crucial aspect found is the ability of this model to train 21st century skills in an integrated manner, including problem solving, collaboration,

critical thinking, and effective communication (Wahyuning, 2022). Empirical validation of the effectiveness of game-based learning was further strengthened through Kusumaningtyas and Yuniawatika's (2024) research which specifically proved the significant effect of wordwall game-based learning on the ability of higher order thinking skills of elementary school students. The paired sample t-test results showed a significant increase between pretest and posttest scores, indicating that the game-based approach was able to optimize students' higher order thinking skills in a measurable way (Suci Hanifah Nahampun et al., 2024). This finding strengthens the argument that game-based learning is not just a fun learning method, but an effective pedagogical instrument for developing complex cognition (Kusumaningtyas & Yuniawatika, 2024). Further exploration by Aryana et al. (2024) revealed a crucial motivational dimension in the implementation of game-based learning. Their research demonstrates that game-based learning media is able to stimulate intrinsic motivation of learners, changing the learning paradigm from burden to pleasure. The crosshictoric innovation developed not only changes the negative perception of learning, but also proves the ability of game-based learning in developing competencies that are relevant to the demands of the technological revolution era. This shows the universality of game-based learning applications across subjects (Aryana et al., 2024).

While some studies have demonstrated the effectiveness of game-based learning, there is a significant research gap in the context of science learning in Indonesian primary schools (Saphira et al., 2023). Previous studies tend to be partial, focusing on certain aspects such as motivation or HOTS separately, but none have comprehensively explored the implementation of game-based learning specifically to improve critical thinking skills in science learning by considering aspects of implementation, effectiveness, and learner responses in an integrated manner. Furthermore, the cultural context and characteristics of Indonesian learners require special adaptations that have not been fully explored in previous studies. The concept of digital game-based learning combines the fun elements of games with learning objectives, creating an interactive, challenging and meaningful learning experience for learners. Given learners' high interest in games, digital-based learning models can be applied to science learning by integrating game elements into the learning process, so that subject matter that is often considered boring can be presented more interestingly (Suryanti et al., 2018). The high interactivity of the game allows students to be actively involved in the learning process, thus increasing their motivation and understanding of the material (Zahro et al., 2025).

However, the implementation of game-based learning also has challenges that need to be overcome. This learning model requires a longer learning curve compared to other learning models, requires more resources and media to ensure learning goes well, and requires good classroom management so that a conducive learning atmosphere can be created (Suprapto et al., 2024). Based on the problems and potentials that have been described, this study aims to analyze the implementation of game-based learning in improving the critical thinking skills of elementary school students in science learning, especially on energy source material. This research is expected to contribute to the development of innovative learning models that can accommodate more interesting and fun learning activities so as to improve students' critical thinking skills, as well as provide practical solutions for teachers in facing learning challenges in the digital era. Thus, this research seeks to answer questions about how the implementation of game-based learning, its effect on improving critical thinking skills, and students' responses to the

application of this learning model in the context of developing critical thinking skills in science subjects.

RESEARCH METHOD

This study uses a quantitative approach with an experimental design to test the effectiveness of the implementation of game-based learning in improving the critical thinking skills of fourth grade students in learning science material on energy sources (Hikmawati, 2020). The experimental design chosen was control group pretest posttest design. The research sample amounted to 90 students divided into three groups, namely 30 students in experimental group 1 (class IV-a Elementary School Tanggul), 30 students in experimental group 2 (class IV-b Elementary School Tanggul), and 30 students in the control group (class IV Elementary School Mulyodadi). The selection of Elementary School Tanggul as the main research location was based on the results of the preliminary study which showed the low critical thinking skills of grade IV students in science subjects. Experimental group 1 received treatment in the form of learning with a game-based learning model based on the digital game "Science Detective", experimental group 2 used an energy source expedition board game, while the control group applied a conventional learning model with the lecture method. The three groups were given the same pretest and posttest to measure the improvement of their critical thinking skills. The research was conducted for one month in semester 2 of the 2024-2025 academic year by involving the fourth-grade teacher as an observer to assess the implementation of learning.

The research instrument consists of three main components that have been validated by experts. First, an observation sheet to observe the implementation of the game-based learning model assessed by two observers using the same instrument during the learning process. Second, critical thinking skills test in the form of pretest and posttest consisting of 8 essay questions prepared based on critical thinking skills indicators including interpretation, analysis, inference, and evaluation. Third, a student response questionnaire using a Likert scale to measure responses to the application of the game-based learning model. The research procedure was carried out through four systematic stages. The preparation stage includes observing the initial conditions of critical thinking skills, literature study, preparation of instruments, and preliminary data analysis (Wijayanti et al., 2017). The planning stage includes the development of learning tools (teaching modules, student worksheet, digital-based game-based learning media), analysis of independent curriculum, analysis of learning outcomes, preparation of pretests and posttests, and preparation of response questionnaires (Amaliyah et al., 2023). The implementation stage begins with giving pretests to all groups, followed by the implementation of the learning model according to each group, giving posttests, and filling out student response questionnaires. The final stage is data management and analysis using a quantitative descriptive approach (Chofifah & Gunansyah, 2024).

Instrument validity was carried out by three expert validators using the average and percentage validity formulas. Learning tools, test sheets, and response questionnaires were validated with the criteria of very valid (85.01%-100.00%), quite valid (70.01%-85.00%), less valid (50.01%-70.00%), and invalid (1.00%-50.00%) (Sugiyono, 2013) . Instrument reliability uses the Borich method (Percentage of Agreement) and SPSS software with Cronbach's alpha, where the instrument is considered reliable if the Cronbach's alpha value> 0.60. Data analysis was done quantitatively through three main aspects. First, analyzing the implementation of game-based learning. Second, analyze the

improvement of critical thinking skills using the N-gain calculation. Third, the analysis of students' responses using a Likert scale. Hypothesis testing is done through a series of statistical tests using SPSS software with alpha 0.05. Normality test is conducted to ensure that the data comes from a normally distributed population, where H_0 is rejected if the significance value <0.05 (Nursalim, 2022). The homogeneity test aims to test the similarity of variance between groups, with data considered homogeneous if the P-value > α. The effectiveness test uses an independent sample t-test to test for significant differences between the three groups, where H_0 is rejected if the Sig. (2-tailed) < 0.05 (Ananda & Fadhli, 2018) . This methodology provides a comprehensive framework to evaluate the effectiveness of game-based learning in improving the critical thinking skills of elementary school learners.

RESULTS AND DISCUSSION

Results

This study aims to analyze the implementation of a game-based learning model using the game media "Science Detective" in class IV Elementary School Tanggul and Elementary School Mulyodadi, with a focus on improving critical thinking skills in science subjects on energy sources. The following is an analysis of the validation and reliability of research instruments from three validators.

Table 1. Results of validation and reliability of research instruments

Instrument	Validity (%)	Validity Category	Cronbach's Alpha	Reliability (%)	Reliability Category
Teaching Module (Experiment)	97.00	Very Valid	0.68	97.00	Very Reliable
Teaching Module (Control)	89.00	Very Valid	0.63	98.00	Very Reliable
Worksheet	98.00	Very Valid	0.64	98.00	Very Reliable
Teaching Materials	91.00	Very Valid	0.64	94.00	Very Reliable
Critical Thinking Test	98.00	Very Valid	0.68	97.00	Very Reliable
"Science Detective" Game Media	94.00	Very Valid	0.70	97.00	Very Reliable
Media "Energy Expedition"	84.00	Fairly Valid	0.64	99.00	Very Reliable
Learner Response Questionnaire	97.00	Very Valid	0.64	97.00	Very Reliable

Based on Table 1, it can be concluded that all research instruments used in the implementation of game-based learning models. The results of this validation and reliability provide confidence that the research instruments developed have met the quality standards needed to measure the effectiveness of the implementation of game-based learning models in improving students' critical thinking skills in science subjects on energy sources (Sudirman & Suriani, 2023). Thus, the research can be continued using these instruments to obtain valid and reliable data.

Table 2. Pretest and Posttest Data

Data	Experimental Class 1		Experimental Class 2		Control Class	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Number of students	30		30		30	
Lowest score	10	67	8	65	10	42
Highest score	38	100	40	95	35	89
Average	26	83	25	80	23	70
N-gain	0,78		0,73		0,61	
Category	High		High		Medium	

Based on Table 2, there is an improvement in learning outcomes in all classes after treatment, both in the experimental classes and the control class. In experimental class 1, which used the digital game media "Detective Science," the students' average pretest score was 26, then increased significantly to 83 in the posttest. The lowest score also rose from 10 to 67, while the highest score increased from 38 to 100. The N-gain value obtained was 0.78 with a high category, indicating that the use of this digital game media is very effective in improving learning outcomes. In experimental class 2, which used the board game media "Expedition," the average pretest score was 25 and increased to 80 in the posttest. The lowest score rose from 8 to 65, and the highest score from 40 to 95. The N-gain value of 0.73 is also in the high category, indicating that this board game media is also effective, although slightly below experimental class 1. Meanwhile, in the control class that did not use game media, the average pretest score was 23 and rose to 70 in the posttest. The lowest score increased from 10 to 42, and the highest score from 35 to 89. The N-gain value of 0.61 is in the medium category, showing a lower improvement compared to both experimental classes.

The improvement in learning outcomes in the experimental classes, particularly in experimental class 1, can occur because the digital game media "Detective Science" is able to provide interactive, challenging learning experiences and encourages students to think critically in solving problems presented in the game. Features such as case simulations, puzzles, and immediate feedback in this digital game can increase student motivation and engagement, making them more active in the learning process. In experimental class 2, the board game media "Expedition" also provides enjoyable and collaborative learning experiences, where students can discuss and work together to complete challenges on the game board. This also contributes to improving critical thinking skills, although not as optimal as the digital game media.

Therefore, the media component that contributes most to improving critical thinking skills is the interactive features and problem-solving elements in the digital game media "Detective Science," as well as the collaborative aspects of the board game "Expedition." Both media proved to be more effective than conventional learning in improving students' learning outcomes and critical thinking skills.

Learning Implementation

Based on the results of observations made by two independent observers, the implementation of the game-based learning model using the "Science Detective" game media shows a very optimal level of implementation. Based on the results of observations made by two independent observers, the implementation of the game-based learning model using the "Science Detective" game media shows a very optimal level of

implementation. Overall, this learning model achieved an average implementation of 96% with the category "Very Well Implemented", which indicates that all stages of learning can be carried out in accordance with the predetermined plan. The results of this analysis indicate that the game-based learning model with game media "Science Detective" can be implemented very effectively in learning science material on energy sources. Before analyzing the effect of game-based learning model, this study fulfills the requirements of parametric statistical analysis through normality and homogeneity tests. The results of the normality test using Shapiro-Wilk showed that all pretest and posttest data from the three classes (control, experiment 1, and experiment 2) were normally distributed with significance values ranging from 0.110 to 0.357, all of which were greater than $\alpha = 0.05$. Similarly, the homogeneity test with Levene's Test yielded significance values of 0.181-0.182 (> 0.05), indicating that the variances between groups were homogeneous. The comparison of each class is presented in Figure 1.

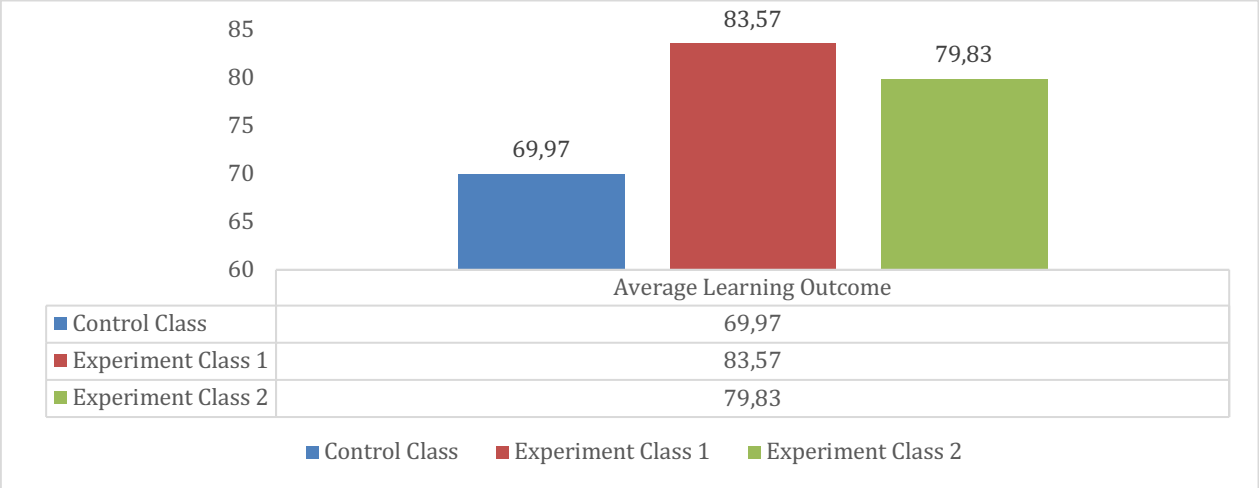

Figure 1. Comparison of average learning outcomes.

Comparison of Control and Experiment Class 1

The results of the independent t-test showed a significant difference between the control and experimental class 1. Experimental class 1 using the "Science Detective" game media achieved an average learning outcome of 83.57, much higher than the control class which only reached 69.97. This average difference of 13.60 points shows the effectiveness of the "Science Detective" game media in improving critical thinking skills. In addition, the standard deviation of experimental class 1 (9.68) was lower than that of the control class (11.81), indicating better consistency of achievement.

Comparison of Control and Experiment Class 2

Experimental class 2 with the "Expedition Board" game media also showed superior results compared to the control class. The average learning outcome of experimental class 2 reached 79.83, with a difference of 9.86 points from the control class. Although the increase was not as high as experimental class 1, this difference was still significant and showed the effectiveness of the game-based learning model.

Comparison of Experiment 1 and Experiment 2 Classes

The comparison between the two experimental classes showed that the "Science Detective" game media (experiment 1) was more effective than the "Expedition Board"

game media (experiment 2). The average difference of 3.74 points (83.57 vs 79.83) indicates that the characteristics of the "Science Detective" game media are more optimal in developing students' critical thinking skills.

Analysis of Critical Thinking Indicators

Analysis based on four critical thinking indicators (interpretation, analysis, inference, evaluation) revealed a consistent pattern (Figure 2).

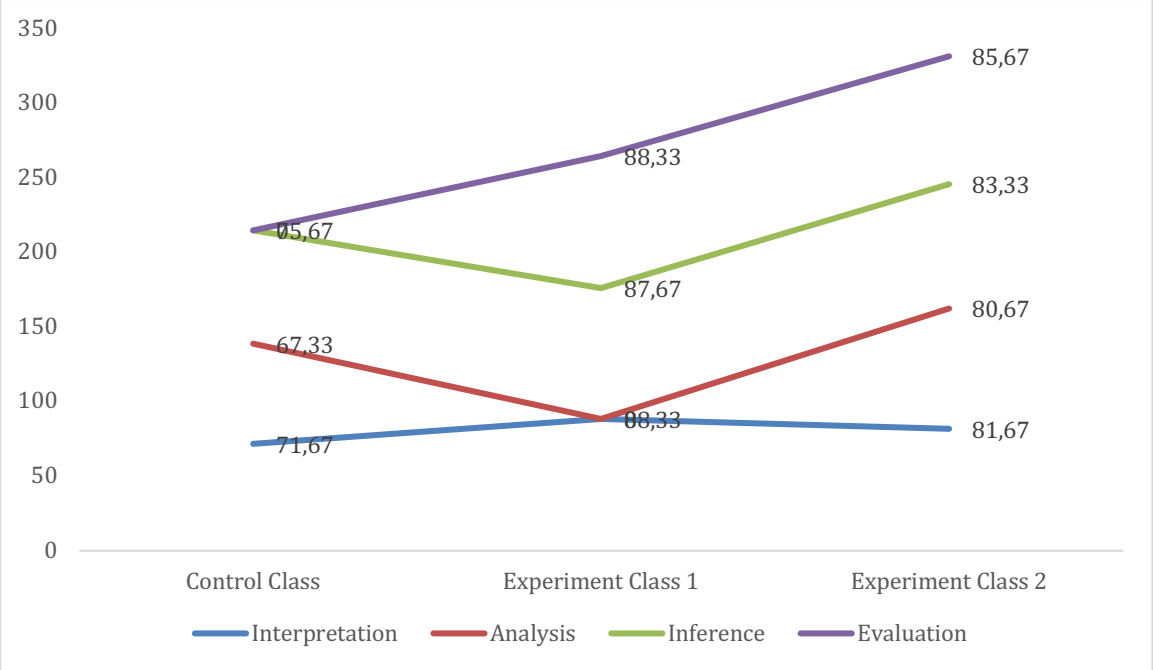

Figure 2. Comparison of average values per indicator.

Analysis based on four critical thinking indicators (interpretation, analysis, inference, evaluation) revealed a consistent pattern:

Control Class

- Highest indicator: Inference (78.00)
- Lowest indicator: Analysis (67.33)
- Variation range: 10.67 points

Experiment Class 1

- Highest indicator: Evaluation (88.33)
- Lowest indicator: Analysis (87.00)
- Range of variation: 1.33 points (very consistent)

Experiment Class 2

- Highest indicator: Evaluation (85.67)
- Lowest indicator: Analysis (80.67)
- Variation range: 5.00 points

Analysis Conclusion

The results consistently showed that the game-based learning model was effective compared to conventional learning in developing critical thinking skills. The "Science Detective" game media proved to be the most effective, followed by the "Expedition Board" game media. Both educational games not only improved overall learning outcomes but also created greater consistency of achievement among learners.

Learner Response

Based on the questionnaire data provided by 30 students, it can be concluded that the "Science Detective" game media received a very positive response and showed a high level of practicality in supporting the science learning process, especially on the material of energy sources and changes in energy sources. Overall, the average value of the questionnaire score reached 55 out of a maximum score of 60 with a percentage of 92.00%, which is included in the very good category. This confirms that the "Science Detective" game media is very practical, effective, and well received by students. This media not only facilitates the understanding of science material, but also increases learning motivation, active involvement, and student enjoyment in the learning process (Salwa Sulaimah Nurhakim et al., 2024). Thus, the application of this game-based learning model is very potential to be further developed as an innovative and fun learning method in elementary schools.

Discussion

Digital media "Science Detective" is a game-based learning innovation that is an interactive digital education platform). This game is designed to develop critical thinking skills of elementary school students in science subjects, especially energy sources. The "Science Detective" game concept adopts an investigative approach where learners play the role of young detectives who must solve various science cases through collecting evidence, analyzing data, and drawing conclusions based on scientific principles (Astindari et al., 2024. Involving learners in learning can increase the meaningfulness of learning, which is the basic philosophy of this game development. This is in line with the trend of modern educational games that prioritize accessibility and ease of use. The platform is designed with responsive design that can be accessed through various devices, ranging from desktop computers, laptops, tablets, to smartphones, facilitating flexible learning according to the condition of technology infrastructure in various schools (Andrean et al., 2025).

The "Science Detective" game can be accessed at the following link: https://detektifsains.rumahkoding.net/. There are 4 levels in the "Science Detective" game, namely mission 1 interpretation, mission 2 analysis, mission 3 inference, and mission 4 evaluation. The advantage of digital media "Science Detective" lies in its ability to present an authentic and contextual learning experience. Each mission in the game is designed based on critical thinking indicators and real science phenomena that are relevant to learners' daily lives, especially the topic of energy sources (Damarsha et al., 2025). This approach is in line with Ausubel's meaningful learning principle, where new learning can be assimilated well when it is connected to learners' prior knowledge and experience (Mashudi & Azzahro, 2020). The following is an image of the "Science Detective" game design in Figure 3.

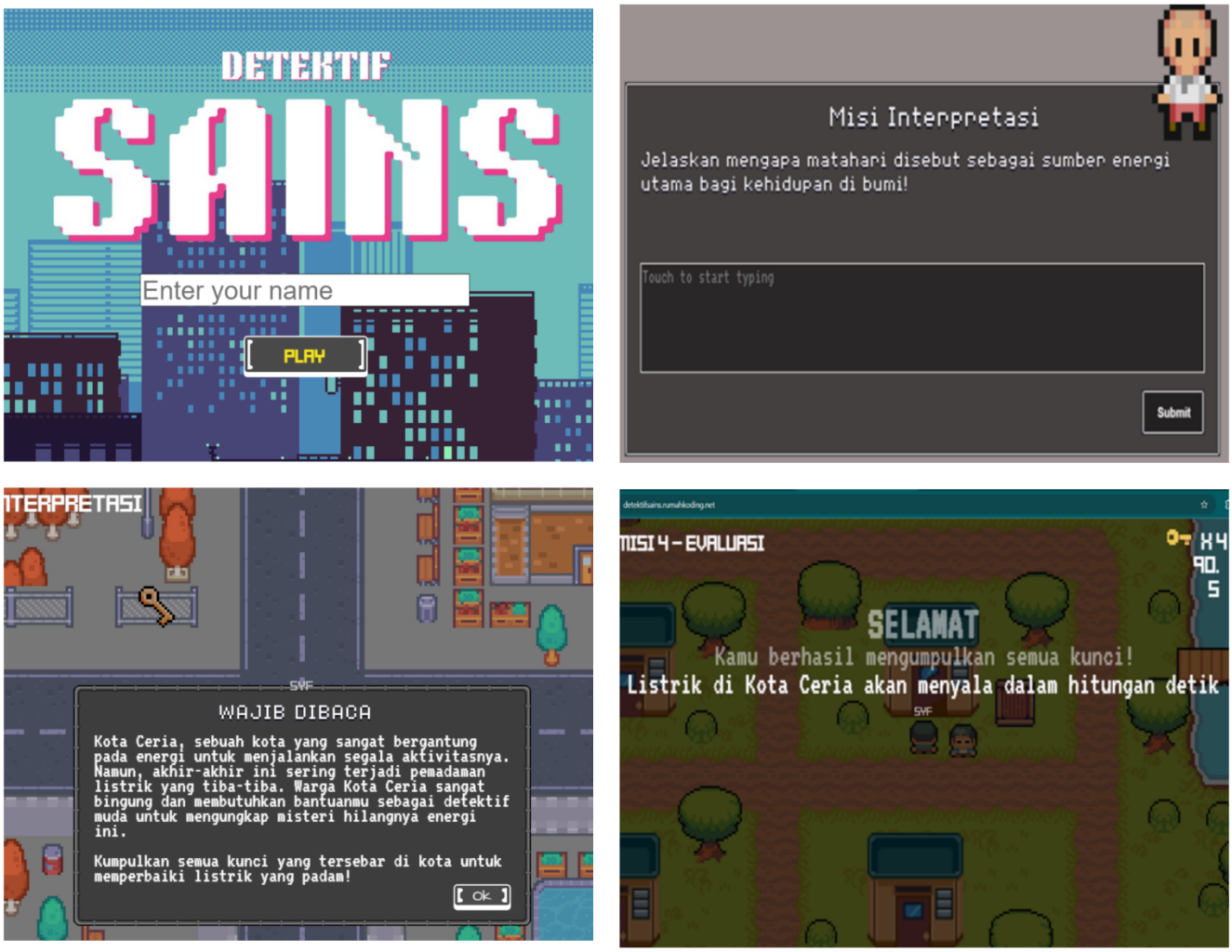

Figure 3. Gaming panel.

The level of implementation of the game-based learning model that reached 96.00% in this study indicates a very effective implementation in the context of science learning in elementary schools. This finding indicates that the game-based learning model is not only theoretically feasible, but also practical to be applied in real learning (Suryanti et al., 2020). These results are in line with Piaget's theory of constructivism which emphasizes that children at primary school age are at the concrete operational stage and need direct experience to build conceptual understanding (Wardani, 2022). The success of this implementation can be explained through several key factors. First, the "Science Detective" game succeeded in providing concrete experiences that facilitated learners' knowledge construction process. This is in accordance with Ausubel's principle of meaningful learning, where new information can be assimilated well when it is connected to existing cognitive structures. Second, the teacher's role as a facilitator in guiding learners through the process of investigation and problem solving creates an optimal zone of proximal development (ZPD), as conceptualized by Vygotsky (Dewi & Reza, 2020).

The results showed that the application of game-based learning model had a significant impact on improving students' critical thinking skills. Experimental class 1 with "Science Detective" media reached an average of 83.57 with N-gain 0.78 (high category), while experimental class 2 with "Expedition Board" media reached an average of 79.83 with N-gain 0.73 (high category). Both results were substantially higher than the control class which only achieved an average of 69.97 with an N-gain of 0.61 (medium

category). The "Science Detective" game can be attributed to the game's intrinsic characteristics that integrate elements of inquiry, data analysis, and evidence-based decision-making. These elements directly activate cognitive processes that are at the core of critical thinking according to Facione's (2011) taxonomy, namely interpretation, analysis, inference, and evaluation (Prahani et al., 2022). Meanwhile, the advantages of both game media over conventional learning confirm the theory of problem-based learning, where learners develop higher order thinking skills through active engagement in authentic problem solving (Azzahra & Darmiyanti, 2024). An interesting finding is the higher homogeneity of learning outcomes in both experimental classes (lower standard deviation) compared to the control class. This indicates that the game-based learning model not only increased the average achievement but also minimized the ability gap between individuals. This phenomenon can be explained through the principle of adaptive scaffolding found in educational games, where each learner gets support according to their ability level (Nurlina et al., 2021).

Analysis per indicator revealed a pattern consistent with cognitive development theory. In experimental class 1, all four critical thinking indicators reached the very high category with a relatively even distribution: evaluation (88.33%), inference (87.67%), analysis (87.00%), and interpretation (83.33%). This balance indicates that the "Science Detective" game can develop critical thinking skills holistically. In contrast, the control class showed a significant disparity between the evaluation-inference indicator (78.00% and 75.67%) and the interpretation-analysis indicator (71.67% and 67.33%). This pattern indicates that conventional learning tends to develop high-level critical thinking skills but is less effective in building a strong analytical foundation(Rahmawati & Sudibyo, 2024) . This finding is in line with criticisms of traditional learning approaches that often emphasize memorization and reproduction of information rather than active knowledge construction.

Theoretically, the results of this study strengthen the validity of constructivist learning theory in the context of elementary school science education. Game-based learning is proven to be able to create a learning environment that supports active knowledge construction , as advocated by Piaget and Vygotsky (Wahab & Rosnawati, 2020). Furthermore, the findings contribute to the understanding of how educational technology can be leveraged to optimize the learning process, particularly in developing higher order thinking skills (Farhin et al., 2023). From a practical perspective, this study provides strong empirical evidence for the implementation of the game-based learning model in the primary school science curriculum. The 92.00% learner acceptance rate indicates that this approach is not only pedagogically effective but also engaging for learners. This is important as motivation and engagement are strong predictors of long-term learning outcomes.

While the results of the study show encouraging findings, some limitations need to be acknowledged. First, the study was conducted in a relatively controlled context of limited duration. Longitudinal research is needed to understand the long-term impact of game-based learning implementation on knowledge retention and transfer of critical thinking skills to other contexts (Thomas, 2024). Secondly, the identified barriers to implementation - particularly the limitations of technological infrastructure and teachers' digital competencies - require special attention in future research. Studies on effective teacher training models for game-based learning implementation as well as adaptation strategies for schools with limited resources are important research areas. Third, this study focused on science subjects with the topic of energy sources. Generalization of the

findings to other subjects and topics requires further validation. Comparative research across subjects can provide a more comprehensive understanding of the relative effectiveness of game-based learning in various learning domains.

This study provides strong empirical evidence that the game-based learning model, particularly through the "Science Detective" game, is an effective approach to develop critical thinking skills of primary school learners. The 96.00% implementation success, significant improvement in all critical thinking indicators, and very high learner acceptance rate (92.00%) confirm the great potential of this approach in transforming science learning in elementary schools. These findings not only contribute to the academic literature on learning innovation, but also provide a practical foundation for the development of educational policies that are more responsive to 21st century learning needs (Irawan, 2023). However, wide-scale implementation requires serious attention to aspects such as teacher capacity building, provision of technological infrastructure, and contextual adaptation according to the specific characteristics of each educational institution.

CONCLUSION

Fundamental Finding: Research on the implementation of game-based learning model in science learning in elementary schools showed very positive results. This model can be implemented well. The application of "Science Detective" and "Expedition Board" media has a significant impact on improving students' critical thinking skills, with N-gain values in the high category compared to the control class which only reached the medium category. The "Science Detective" game showed more comprehensive excellence in all critical thinking indicators, while "Expedition Board" excelled in evaluation and inference indicators. Learners' responses were very positive, in the "Excellent" category, indicating increased motivation and active engagement in learning. **Limitation:** However, there are still challenges related to technology infrastructure, teachers' digital competencies, and curriculum integration. **Implication:** Based on the research findings, it is recommended for educators to integrate game-based learning models as an alternative to science learning and develop technological skills through continuous training. Schools need to provide adequate technology infrastructure and facilitate teacher professional development programs. Learning media developers are expected to design games that pay attention to pedagogical aspects and are adaptive to the needs of diverse learners. **Future Research:** Future researchers are advised to conduct further research on different subjects and levels of education. Education policy makers need to consider the integration of game-based learning into the national curriculum with budget support for technology infrastructure and teacher training.

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***Sinta Yuni Fitanti, M.Pd. (Corresponding Author)**
Surabaya State University, Surabaya, Indonesia
Jl. Ketintang, Surabaya, East Java, 60231, Indonesia
Email: 24010855044@mhs.unesa.ac.id

Dr. Binar Kurnia Prahani
Department of Physics Education,
Surabaya State University, Surabaya, Indonesia
Jl. Ketintang, Surabaya, East Java, 60231, Indonesia
Email: binarprahani@unesa.ac.id

Prof. Dr. Suryanti, M.Pd.
Surabaya State University, Surabaya, Indonesia
Jl. Ketintang, Surabaya, East Java, 60231, Indonesia
Email: suryanti@unesa.ac.id

Hanandita Veda Saphira
Faculty of the Arts, Social Sciences and Humanities,
University of Wollongong, Australia
Email: hvs346@uowmail.edu.au