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IFP-BASED LEARNING INTEGRATED WITH TRADITIONAL GAMES FOR MATHEMATICAL ABSTRACTION AND CRITICAL LITERACY

PEMBELAJARAN BERBASIS IFP YANG TERINTEGRASI DENGAN PERMAINAN TRADISIONAL UNTUK ABSTRAKSI MATEMATIKA DAN LITERASI KRITIS

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Abstract

This study examined the implementation of Interactive Flat Panel (IFP)-based learning integrated with traditional games to enhance mathematical abstraction and critical literacy among elementary students. Using a mixed-methods implementation research design, the study involved 89 fourth-grade students, 10 teachers, and one principal at SDN Meduri 2 Margomulyo. Data were collected through pretests, posttests, observations, interviews, and documentation. Results showed improvements in mathematical abstraction and critical literacy. Qualitative findings revealed greater student engagement, conceptual understanding, reasoning, and participation in discussions. The integration of traditional games and IFP technology provided meaningful learning contexts that supported abstract reasoning and critical analysis. The findings suggest that technology-supported contextual learning can effectively promote higher-order thinking skills in elementary mathematics education.

Keywords: *Interactive Flat Panel (IFP), Mathematical Abstraction, Critical Literacy*

Abstrak

Penelitian ini mengkaji implementasi pembelajaran berbasis Interactive Flat Panel (IFP) yang diintegrasikan dengan permainan tradisional untuk meningkatkan abstraksi matematis dan literasi kritis siswa sekolah dasar. Penelitian menggunakan desain implementation research dengan pendekatan mixed methods yang melibatkan 89 siswa kelas IV, 10 guru, dan satu kepala sekolah di SDN Meduri 2 Margomulyo. Data dikumpulkan melalui pretest, posttest, observasi, wawancara, dan dokumentasi. Hasil penelitian menunjukkan peningkatan kemampuan abstraksi matematis dan literasi kritis. Temuan kualitatif menunjukkan peningkatan keterlibatan siswa, pemahaman konsep, kemampuan bernalar, dan partisipasi dalam diskusi. Integrasi permainan tradisional dan teknologi IFP menciptakan konteks belajar yang bermakna sehingga mendukung penalaran abstrak dan analisis kritis. Temuan ini menunjukkan potensi pembelajaran kontekstual berbantuan teknologi dalam mengembangkan keterampilan berpikir tingkat tinggi pada pembelajaran matematika sekolah dasar.

Kata Kunci: *Interactive Flat Panel (IFP), Abstraksi Matematis, Literasi Kritis*

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1. Introduction

The rapid advancement of digital technology has transformed educational practices worldwide, requiring schools to develop learners capable of critical thinking, problem-solving, communication, collaboration, and responsible participation in increasingly complex digital environments. Within the framework of twenty-first-century education, learning is expected to move beyond the transmission of knowledge toward the development of higher-order cognitive competencies that enable students to interpret information critically, construct knowledge independently, and apply their understanding in authentic contexts (Halim, 2022; OECD, 2023). Consequently, elementary education plays a crucial role in establishing foundational cognitive skills that support lifelong learning and academic success.

Among the competencies emphasized in contemporary education, critical literacy and mathematical abstraction are particularly important. Critical literacy refers to the ability to analyze, evaluate, and interpret information from multiple perspectives rather than merely comprehending texts at a surface level. In digital environments characterized by abundant information and misinformation, students need critical literacy skills to assess the credibility of information, identify assumptions, and make informed judgments. Recent studies have highlighted that critical digital literacy is increasingly essential for enabling students to navigate information-rich environments and participate effectively in knowledge construction processes (A'isyah, Kamalia, Bawana, Jannah, & Yuanita, 2025; Ilomäki, Lakkala, Kallunki, Mundy, Romero, Romeu, & Anastasia, 2023). Simultaneously, mathematical abstraction enables learners to identify patterns, generalize relationships, connect concrete experiences with symbolic representations, and develop conceptual understanding beyond procedural computation (Kurniati, Dahlan, Madubun, Afifa, Dahoklory, Dahliani, Bayu, Putra, Mutmainna, Yuhasriati, Ainun, & Lubis, 2025; OECD, 2023).

The relationship between critical literacy and mathematical abstraction is particularly significant in mathematics learning. Solving contextual mathematical problems requires students to interpret information, distinguish relevant and irrelevant data, evaluate possible solution strategies, and translate real-world situations into mathematical representations. According to the OECD mathematics framework, mathematical literacy involves formulating, employing, and interpreting mathematics in real-world contexts, all of which require critical reasoning and abstraction processes (OECD, 2023). Previous studies also indicate that students' ability to understand contextual mathematical situations is closely associated with literacy and reasoning competencies (Ramadhani, Agung, Izzania, Sari, & Supriatna, 2021). Therefore, the development of critical literacy and mathematical abstraction should be viewed as complementary educational objectives rather than separate competencies.

Despite their importance, numerous studies indicate that elementary school students continue to experience difficulties in developing conceptual understanding of mathematics and higher-order thinking skills. Limited opportunities for inquiry, reasoning, and meaningful problem solving often result in students relying on memorization and procedural approaches rather than conceptual understanding (Ramadhani, Agung, Izzania, Sari, & Supriatna, 2021). Similar findings have been reported internationally, where students frequently struggle to connect mathematical representations with meaningful contexts and to apply mathematical reasoning beyond routine procedures (OECD, 2023).

Preliminary observations conducted in grade IV at SDN Meduri 2 Margomulyo revealed similar challenges in mathematics learning, as 18 of the 21 observed students experienced difficulties in understanding multiplication concepts. Most students relied on repetitive counting strategies and demonstrated limited understanding of multiplication as repeated addition or grouping. They also encountered difficulties interpreting contextual problems and translating verbal information into mathematical representations. These findings suggest that students' difficulties are not merely computational in nature but are closely related to weaknesses in mathematical abstraction and literacy processes, which are essential for meaningful mathematical understanding (OECD, 2023; Ramadhani, Agung, Izzania, Sari, & Supriatna, 2021).

Further classroom observations indicated that students often used inefficient and time-consuming manual calculation methods when solving multiplication problems. They had difficulty visualizing groups of objects as quantitative units and were unable to connect concrete experiences to symbolic mathematical representations. As a result, multiplication remained an abstract and disconnected concept rather than a meaningful mathematical idea grounded in students' everyday experiences. This condition is particularly concerning because multiplication serves as a foundational concept for subsequent mathematical topics such as division, fractions, ratios, algebraic thinking, and proportional reasoning. Without a solid understanding of multiplication, students may encounter persistent difficulties in mastering more advanced mathematical concepts in later grades.

This finding is consistent with the Technological Pedagogical Content Knowledge (TPACK) perspective, which emphasizes that educational technology contributes to learning only when it is integrated through appropriate pedagogical strategies rather than merely being available in classrooms. Recent studies on interactive educational technologies similarly demonstrate that the effectiveness of digital tools depends largely on pedagogical implementation and teacher readiness (Müller, Otero, & Milrad, 2024).

Interactive Flat Panels (IFP) offer considerable potential for supporting mathematics learning by facilitating visualization, interaction, collaboration, and immediate feedback. Recent studies have shown that interactive digital displays can enhance student engagement and promote active participation by enabling learners to manipulate representations directly and collaboratively explore concepts (Müller, Otero, & Milrad, 2024). Similar findings indicate that IFP-supported learning environments improve students' conceptual understanding by transforming abstract mathematical ideas into more accessible visual experiences (Sari, Muthoharoh, Murhartoyo, Aslamiah, & Amelia, 2026).

In addition to technology integration, meaningful learning contexts are required to help students bridge concrete experiences and abstract mathematical concepts. Traditional games provide culturally familiar situations that naturally involve counting, grouping, comparing quantities, evaluating strategies, and collaborative decision-making. Such activities create opportunities for students to construct mathematical meaning through direct experience while simultaneously engaging in discussion, reasoning, and reflection. Previous studies have shown that game-based learning can enhance student motivation, conceptual understanding, and active participation in mathematics learning (Müller, Otero, & Milrad, 2024; Jumiati, Sulistyawan, & Siswandi, 2025). Therefore, integrating traditional games into technology-supported learning environments may provide a promising approach to strengthening both mathematical abstraction and critical literacy.

Previous studies have reported positive effects of game-based learning on mathematical understanding and student engagement, while other studies have demonstrated the benefits of interactive technologies for enhancing classroom interaction and learning outcomes (Müller, Otero, & Milrad, 2024; Jumiati, Sulistyawan, & Siswandi, 2025). However, most existing studies have examined these approaches separately. Research on traditional games has generally focused on motivation, cultural preservation, or mathematical understanding, whereas studies on IFP have primarily emphasized technological interaction and student engagement. Limited research has investigated the integration of traditional game-based learning and IFP technology to simultaneously foster mathematical abstraction and critical literacy among elementary school students, particularly in multiplication learning contexts.

Therefore, this study proposes the implementation of IFP-based learning integrated with traditional games through the Indonesia Cerdas application as an innovative instructional approach in elementary mathematics education. The novelty of this study lies in integrating culturally contextualized traditional games and IFP technology within a single learning environment designed to foster both mathematical abstraction and critical literacy. Unlike previous studies that examined game-based learning and interactive technologies separately, this study investigates their combined implementation in elementary multiplication learning. Accordingly, this study aims to examine how IFP-based learning integrated with traditional games facilitates the development of students' mathematical abstraction and critical literacy skills.

2. Research Method

This study employed a mixed-methods implementation research design to examine the implementation of IFP-based learning integrated with traditional games in fostering mathematical abstraction and critical literacy among elementary school students. The study focused on evaluating the effectiveness of an existing instructional intervention rather than developing a new learning product. Therefore, the research focused on the implementation process, student learning outcomes, and participants' perceptions of IFP-supported learning activities.

The study was conducted at SDN Meduri 2 Margomulyo, Bojonegoro Regency, East Java, Indonesia, during the 2025/2026 academic year. The participants consisted of 89 fourth-grade students aged 9–10 years who participated in the learning activities. The students were distributed across four grade IV classes and had previously studied basic multiplication concepts. In addition, ten classroom teachers and one principal participated as informants in observations and interviews. Purposive sampling was employed because participants were directly involved in mathematics learning activities utilizing IFP media and the Indonesia Cerdas application.

The implementation was conducted through four learning stages designed to support students' progression from concrete to abstract thinking. At the concrete stage, students observed traditional game situations depicted in the IFP, such as tug-of-war and greased-pole climbing. They identified the quantities and groups represented in the games. During the semi-concrete stage, students interacted with digital images and visual representations to classify objects and identify numerical relationships. At the semi-abstract stage, students represented situations using repeated addition and explained their reasoning verbally. Finally, at the abstract stage, students expressed mathematical relationships using multiplication symbols and mathematical expressions while engaging

in critical discussions, evaluating strategies, and providing evidence-based arguments. Figure 1 illustrates the progression from concrete experiences to abstract mathematical reasoning through IFP-supported learning activities.

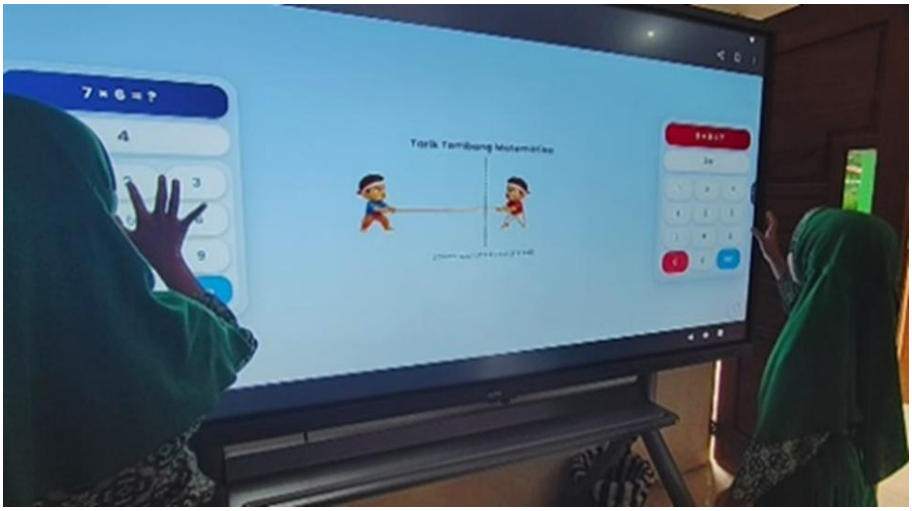


Figure 1. Stages of IFP-Based Learning Integrated with Traditional Games

Data were collected through tests, observations, interviews, and documentation. Each instrument served a specific purpose in capturing students' learning outcomes and implementation processes. The tests were used to measure changes in students' mathematical abstraction and critical literacy skills before and after the intervention. Observations were conducted to examine student participation, interaction patterns, and learning behaviors during implementation. Interviews were used to explore participants' experiences, perceptions, and challenges related to IFP-based learning. Documentation was collected to support data triangulation and provide evidence of learning activities and student performance.

The test instrument consisted of a pretest and a posttest administered to all 89 students. The mathematical abstraction section included eight open-ended items assessing students' abilities to identify patterns, classify objects, represent situations symbolically, establish mathematical relationships, and generalize concepts. The critical literacy section consisted of seven contextual items requiring students to interpret information, analyze situations, evaluate arguments, distinguish relevant from irrelevant information, and provide evidence-based justifications. The tests were validated by two mathematics education experts and one elementary education expert before implementation.

Classroom observations were conducted throughout the implementation using structured observation sheets completed by researchers and classroom teachers. The observation instrument consisted of five aspects: (1) student participation, (2) interaction with IFP media, (3) engagement in collaborative discussions, (4) problem-solving behavior, and (5) progression from concrete to abstract thinking. Observations were conducted during every learning session to capture students' responses and engagement throughout the intervention.

Semi-structured interviews were conducted after the implementation phase. Interview participants included ten classroom teachers, one principal, and nine students selected using purposive sampling to represent high, medium, and low achievement groups based on posttest results. Teacher and principal interviews focused on perceptions

of IFP utilization, instructional benefits, implementation challenges, and observed student learning development. Student interviews explored learning experiences, engagement, conceptual understanding, and perceptions regarding traditional game-based learning activities.

Documentation data included lesson plans, teaching materials displayed through the IFP, photographs of classroom activities, students' worksheets, students' written responses, assessment records, and field notes. These documents were analyzed to provide supporting evidence regarding learning implementation, student participation, and the development of mathematical abstraction and critical literacy skills.

Quantitative data obtained from the pretest and posttest were analyzed using descriptive statistics, including mean scores, percentage gains, minimum and maximum scores, and n-gain analysis. Qualitative data obtained from observations, interviews, and documentation were analyzed through data reduction, data display, and conclusion drawing. To enhance trustworthiness, methodological triangulation was conducted by comparing findings across multiple instruments and participant groups. The integration of quantitative and qualitative findings was used to evaluate the effectiveness of the implemented IFP-based learning in fostering mathematical abstraction and critical literacy among elementary school students.

3. Results and Discussion

3.1 Results

3.1.1 Pretest Results of Mathematical Abstraction Ability

Table 1. Results of the Mathematical Abstraction Ability Pretest

No	Indicator	Score
1	Average	58.4
2	Highest Score	85.0
3	Lowest Score	40.0
4	Completion	31%

Based on table 1, the pretest results indicate that students' mathematical abstraction abilities remained relatively low. The average score was 58.4, indicating that most students had not yet fully understood multiplication concepts. The completion percentage of only 31% also shows that the majority of students had not reached the expected learning criteria.

The quantitative findings were supported by classroom observations conducted before the implementation of the IFP-based learning. Observations showed that most students solved multiplication problems by counting objects one by one rather than applying grouping or repeated addition strategies. Students also experienced difficulties when asked to represent concrete situations using mathematical symbols. Classroom participation was relatively low, and only a few students actively responded to the teacher's questions.

Interview results with teachers further confirmed these findings. One teacher explained that students tended to memorize multiplication facts without fully understanding the underlying concepts. Another teacher stated that students frequently relied on teacher guidance when solving mathematical problems and had difficulty

explaining their reasoning. Documentation in the form of students' worksheets also supported these findings. Several students used repetitive counting strategies, while others were unable to complete questions that required abstract mathematical representations. These findings indicate that students' abilities to abstract in mathematics remained limited before the intervention.

3.1.2 Critical Literacy Pretest Results

Table 2. Results of the Critical Literacy Pretest

No	Indicator	Score
1	Average	60.2
2	Highest Score	88.0
3	Lowest Score	42.0
4	Completion	35%

Based on table 2, the pretest results indicate that students' critical literacy skills remained relatively low. The average score of 60.2 suggests that most students had difficulty analyzing information critically and providing logical arguments to support their answers. Classroom observations revealed that students generally answered questions directly without explaining the reasons behind their responses. During discussions, only a few students actively participated, while most remained passive. Furthermore, students experienced difficulty identifying important information and evaluating different perspectives presented in learning activities. Teacher interviews also indicated that students rarely questioned information critically and tended to accept information without deeper analysis. Teachers reported that students often struggled to justify their answers when asked to provide explanations.

Documentation of students' answer sheets showed that many responses were brief and lacked supporting arguments. This evidence reinforces the quantitative results, indicating that students' critical literacy skills were still underdeveloped before the learning intervention.

3.1.3 Mathematical Abstraction Posttest Results

Table 3. Results of the Mathematical Abstraction Posttest

No	Indicator	Score
1	Average	82.6
2	Highest Score	98.0
3	Lowest Score	65.0
4	Completion	83%

Based on table 3, the posttest results show a substantial improvement in students' mathematical abstraction abilities. The average score increased from 58.4 to 82.6, while learning completion increased from 31% to 83%. These quantitative improvements were consistent with classroom observation findings. During the learning process, students demonstrated greater ability to identify patterns, apply grouping strategies, and represent multiplication concepts symbolically. Students actively interacted with learning materials displayed on the IFP and participated more confidently in classroom discussions.

Teacher interviews revealed that students became more capable of explaining mathematical concepts and solving problems independently. Teachers also reported that the IFP's visual and interactive features helped students connect concrete experiences with abstract mathematical concepts. Documentation in the form of student worksheets and photographs of learning activities further showed improvements in students' use of multiplication symbols, grouping models, and mathematical reasoning. Compared to the pretest stage, students demonstrated stronger conceptual understanding and greater accuracy in solving mathematical problems.

3.1.4 Critical Literacy Posttest Results

Table 4. Results of the Critical Literacy Posttest

No	Indicator	Score
1	Average	84.1
2	Highest Score	96.0
3	Lowest Score	68.0
4	Completion	85%

Based on table 4, the posttest results demonstrate a significant improvement in students' critical literacy skills. The average score increased from 60.2 to 84.1, while the completion rate rose from 35% to 85%. Observation data showed that students became more active in discussions, asked questions more frequently, and provided logical explanations to support their answers. Students were also able to analyze information, compare alternative solutions, and evaluate their peers' reasoning during classroom activities.

Teacher interviews indicated that students showed increased confidence in expressing opinions and defending their ideas. Teachers observed that students were more engaged in collaborative discussions and demonstrated stronger critical thinking abilities throughout the learning process. Documentation findings supported these observations. Students' written responses became more detailed and analytical, and classroom documentation showed active participation in group discussions and problem-solving activities. These findings strengthen the evidence that implementing IFP-based learning positively contributed to the development of students' critical literacy skills.

3.1.5 N-Gain Analysis Results

To further examine the effectiveness of the implemented learning intervention, a normalized gain (n-gain) analysis was conducted. The n-gain score was used to measure the magnitude of improvement in students' mathematical abstraction and critical literacy skills by comparing pretest and posttest results. This analysis provides additional information regarding the extent to which the IFP-based learning integrated with traditional games contributed to students' learning progress. The results of the n-gain analysis are presented in table 5.

Table 5. Results of the N-Gain Analysis

Variable	Pretest Mean	Posttest Mean	N-Gain	Category
Mathematical Abstraction	58.40	82.60	0.58	Moderate

Variable	Pretest Mean	Posttest Mean	N-Gain	Category
Critical Literacy	60.20	84.10	0.60	Moderate

Based on table 5, the n-gain analysis indicates that both mathematical abstraction and critical literacy skills improved after the implementation of IFP-based learning integrated with traditional games. Mathematical abstraction achieved an n-gain score of 0.58, while critical literacy achieved an n-gain score of 0.60. According to Hake's classification, both scores fall within the moderate category, indicating that the learning intervention was effective in improving students' abilities in both domains.

The results suggest that integrating IFP technology with traditional game-based learning provided meaningful learning experiences that supported students' cognitive development. The improvement in mathematical abstraction reflects students' increasing ability to identify patterns, represent situations symbolically, and generalize mathematical relationships. Similarly, the improvement in critical literacy indicates that students became more capable of interpreting information, analyzing situations, evaluating arguments, and providing logical justifications for their responses.

The slightly higher n-gain score for critical literacy (0.60) compared to mathematical abstraction (0.58) suggests that the learning activities not only supported conceptual mathematical understanding but also encouraged discussion, reflection, and reasoning processes. Through traditional game contexts and interactive classroom discussions facilitated by the IFP, students were given opportunities to engage actively with information, compare alternative solutions, and communicate their ideas. These experiences contributed to the development of critical literacy alongside mathematical abstraction.

3.1.6 Improved Conceptual Understanding through Visual Representation

The qualitative findings from classroom observations, interviews, and documentation supported the quantitative results and provided a deeper understanding of how IFP-based learning, when integrated with traditional games, contributed to the development of students' mathematical abstraction and critical literacy skills. Three major themes emerged from the data analysis: (1) improved conceptual understanding through visual representation, (2) increased student participation and engagement, and (3) enhanced reasoning and critical discussion skills.

Classroom observations indicated that students demonstrated a better understanding of multiplication concepts after participating in the learning activities. The visual representations in the IFP enabled students to identify groups, recognize repeated-addition patterns, and gradually connect concrete situations to symbolic mathematical expressions. During the initial observations, many students counted objects individually, whereas during the intervention, they increasingly used grouping strategies and multiplication notation. Teacher interviews also supported this finding. One teacher (T3) stated:

> *"Students who previously counted objects one by one began to recognize groups and directly relate them to multiplication concepts. The visual displays helped them understand the meaning behind the operation rather than simply memorizing multiplication facts."*

Documentation in the form of students' worksheets showed that students progressively used multiplication symbols more accurately and were able to explain the relationships between visual representations and mathematical expressions.

3.1.7 Increased Student Participation and Engagement

Observation data revealed a noticeable increase in student participation during classroom activities. Students actively interacted with the IFP, volunteered to answer questions, and participated in collaborative discussions more frequently than during conventional lessons. Traditional game scenarios presented through the Indonesia Cerdas application appeared to create a more engaging learning atmosphere that encouraged students to become actively involved in learning activities. A classroom teacher (T7) explained:

> *"Students were much more enthusiastic when learning activities involved traditional games. Even students who were usually passive became willing to participate in discussions and present their ideas."*

Photographic documentation and field notes also showed that students remained engaged throughout the learning sessions and demonstrated greater willingness to collaborate with their peers.

3.1.8 Enhanced Reasoning and Critical Discussion Skills

The interview and observation data further indicated improvements in students' critical literacy skills. Students increasingly provided explanations for their answers, compared alternative solution strategies, and evaluated their peers' reasoning. During group discussions, students were observed asking questions, defending their arguments, and responding to different viewpoints. One teacher (T5) commented:

> *"Students became more confident in expressing opinions and explaining why they chose a particular answer. They no longer focused only on obtaining the correct result but also on explaining the process used to reach it."*

Similarly, several students reported that discussing game strategies and problem-solving approaches helped them better understand mathematical concepts. Analysis of students' written responses showed that post-intervention responses were generally more detailed, logical, and supported by appropriate explanations than their pretest responses.

Table 6. Summary of Qualitative Findings

Theme	Evidence from Observation	Evidence from Interview	Evidence from Documentation
Improved conceptual understanding	Students used grouping strategies and multiplication symbols	Teachers reported better conceptual understanding	Worksheets showed an accurate symbolic representation
Increased participation and engagement	Students actively interacted with IFP and discussions	Teachers observed higher enthusiasm	Photographs showed active participation

Theme	Evidence from Observation	Evidence from Interview	Evidence from Documentation
Enhanced reasoning and critical literacy	Students justified their answers and evaluated alternatives	Teachers reported stronger reasoning skills	Written responses became more analytical

Overall, the qualitative findings indicate that integrating IFP technology with traditional game-based learning not only improved students' learning outcomes but also promoted active engagement, conceptual understanding, reasoning, and the development of critical literacy throughout the learning process.

3.2 Discussion

The findings demonstrated substantial improvements in students' mathematical abstraction and critical literacy skills following the implementation of IFP-based learning integrated with traditional games. The increase in posttest scores and n-gain values indicates that the intervention effectively supported both conceptual understanding and the development of higher-order thinking. These findings are consistent with previous studies showing that technology-enhanced and game-based learning environments can positively influence students' cognitive achievement, engagement, and mathematical performance. Systematic reviews have reported that game-based mathematics learning contributes not only to academic achievement but also to motivation, participation, and active learning behaviors, which are important factors in improving learning outcomes (Kacmaz & Dubé, 2022; Tokac, Novak, & Thompson, 2019).

The improvement in mathematical abstraction suggests that students gradually progressed from concrete experiences toward symbolic mathematical reasoning. Initially, many students relied on counting objects individually, indicating a dependence on concrete representations. However, after the intervention, students increasingly used grouping strategies, repeated addition, and multiplication symbols independently. This progression supports the view that mathematical understanding develops through successive representational stages in which learners connect concrete experiences with increasingly abstract representations. Interactive visual environments facilitate this transition by enabling students to manipulate representations and observe mathematical relationships dynamically (Ye, Liang, Ng, & Chai, 2023; Yeung & Ng, 2023). Similar findings have been reported in studies emphasizing the importance of technology-supported representations in strengthening conceptual understanding and mathematical reasoning (Ye, Liang, Ng, & Chai, 2023).

The IFP played an important role in supporting conceptual learning by enabling students to interact directly with visual representations of mathematical ideas. Unlike traditional instruction, where students often receive information passively, the IFP allowed students to manipulate objects, observe patterns, and receive immediate feedback. Such interactive experiences are known to promote active knowledge construction and deeper cognitive processing (Bedenlier, Bond, Buntins, Richter, & Kerres, 2020). Research on touchscreen-based mathematics learning environments has shown that direct manipulation and embodied interaction can strengthen mathematical meaning-making processes, particularly among elementary school students who are transitioning from concrete to abstract thinking (Müller, Otero, & Milrad, 2024; Yeung & Ng, 2023).

The significant improvement in critical literacy indicates that students became increasingly capable of interpreting information, analyzing situations, evaluating alternative solutions, and providing evidence-based explanations. Before the intervention, many students tended to provide short answers without justification. Following implementation, students were more likely to explain their reasoning, defend their conclusions, and evaluate their peers' arguments. These findings suggest that learning activities involving discussion, reflection, and collaborative problem-solving can effectively foster critical literacy (Ilomäki, Lakkala, Kallunki, Mundy, Romero, Romeu, & Anastasia, 2023; Kaeophanuek, Jaitip, & Nilsook, 2018). Contemporary educational research emphasizes that critical literacy develops when learners actively engage with information, construct arguments, and evaluate multiple perspectives rather than simply passively receiving knowledge.

An important finding of this study is that the improvement cannot be attributed solely to technology use. The integration of traditional games provided meaningful, culturally familiar contexts for students to explore mathematical ideas. Activities such as tug-of-war and greased-pole climbing enabled students to visualize grouping, compare quantities, discuss strategies, and evaluate outcomes. Previous reviews have demonstrated that game-based learning enhances both cognitive and affective domains by creating opportunities for active participation, problem-solving, and social interaction (Byun & Eisenmann, 2024; Tokac, Novak, & Thompson, 2019). Furthermore, game-based environments encourage students to focus on reasoning processes rather than merely on obtaining correct answers, thereby supporting both mathematical abstraction and the development of critical literacy (Byun & Eisenmann, 2024).

The findings also indicate a close relationship between mathematical abstraction and critical literacy. Students who demonstrated stronger conceptual understanding were generally better able to explain their reasoning and justify their solutions. Likewise, students who actively evaluated information and discussed alternative strategies appeared better able to construct abstract mathematical representations. This relationship suggests that abstraction and literacy are not independent competencies but mutually reinforcing processes. When students engage in reasoning, argumentation, and explanation, they simultaneously strengthen conceptual understanding and communication skills (OECD, 2023). Similar conclusions have been reported in studies highlighting the interconnected nature of reasoning, representation, and literacy within mathematics learning environments (Ye, Liang, Ng, & Chai, 2023).

The results provide important implications for elementary mathematics instruction. The effectiveness of the intervention appears to derive from the interaction between technology, pedagogy, and contextual learning experiences rather than from technological tools alone. While IFP provided visualization and interactivity, traditional games supplied meaningful contexts that encouraged discussion, reasoning, and collaboration. Previous research has similarly emphasized that educational technology produces meaningful learning outcomes only when supported by effective pedagogical design and active student engagement (Sun, Kangas, & Ruokamo, 2024). Therefore, teachers should focus not only on adopting digital tools but also on designing learning experiences that connect technology with authentic contexts and collaborative inquiry.

Compared with previous studies that examined interactive technologies and game-based learning separately, this study contributes to the literature by demonstrating how integrating IFP technology with traditional game-based learning can simultaneously support mathematical abstraction and critical literacy development. The findings suggest

that culturally relevant learning contexts combined with interactive digital technologies create opportunities for students to develop conceptual understanding, reasoning, communication, and critical thinking in an integrated manner. Consequently, the study extends existing knowledge by highlighting the importance of combining technological innovation with meaningful pedagogical strategies to support holistic learning outcomes in elementary mathematics education.

4. Conclusion

This study concludes that the integration of IFP-based learning with traditional games positively contributes to the development of elementary school students' mathematical abstraction and critical literacy skills. The quantitative findings showed substantial improvements in both variables, as reflected in the increased posttest scores and moderate n-gain values. Students demonstrated greater ability to identify patterns, represent mathematical situations symbolically, generalize relationships, interpret information, analyze problems, and provide logical justifications for their responses. The qualitative findings further revealed that integrating interactive digital technology with culturally relevant traditional games created meaningful learning experiences that enhanced student engagement, participation, reasoning, and collaborative discussion. The IFP facilitated the transition from concrete experiences to abstract mathematical understanding, while traditional games provided authentic contexts that encouraged critical reflection and problem-solving. These findings suggest that the effectiveness of educational technology depends not only on technological features but also on its pedagogical integration within contextual and student-centered learning environments. Therefore, IFP-based learning integrated with traditional games can serve as an innovative instructional approach for fostering both mathematical abstraction and critical literacy in elementary mathematics education.

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