International Journal of Applied Mathematics

Volume 38 No. 11s 2025,

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

INTERACTIVE FLAT PANEL MEDIA TO ENHANCE MATHEMATICAL ABSTRACTION SKILLS IN ELEMENTARY STUDENTS

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Abstract

Mathematical abstraction is an important skill that enables elementary school students to move from concrete understanding to symbolic reasoning. However, many students still have difficulty understanding abstract concepts, especially in the subject of perimeter and area of flat shapes. This difficulty arises because learning is still predominantly focused on memorizing formulas without giving students the opportunity to explore visual representations and cognitive activities that support the formation of mathematical generalizations. The use of Interactive Flat Panels (IFPs) offers a strategic alternative because this interactive digital media is capable of presenting animations, simulations, virtual manipulatives, and drag-and-drop activities that support students' transition from concrete objects to mathematical images and symbols. This study used a quasi-experimental design with a pretest-posttest control group model to test the effectiveness of using Interactive Flat Panels in improving students' mathematical abstraction skills. The results show that the experimental group experienced a significant improvement compared to the control group. Statistical analysis using the t-test shows a significant difference in the posttest results of the two groups. In addition, classroom observations show that students who use the Interactive Flat Panel are more active, enthusiastic, and able to generalize the concepts of perimeter and area better with the help of digital visualization. These findings confirm that the Interactive Flat Panel is not only effective in improving the understanding of the concepts of perimeter and area of flat shapes, but also plays an important role in supporting the gradual development of mathematical abstraction skills in accordance with the cognitive development stage of students.

Keywords: Interactive Flat Panel, mathematical abstraction, elementary school students, perimeter, area, digital manipulatives.

Received: August 06, 2025

International Journal of Applied Mathematics

Volume 38 No. 11s 2025,

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

I. Introduction

Mathematical abstraction is a fundamental competency that forms the basis for the development of reasoning, problem-solving, and understanding advanced concepts in mathematics. At the elementary school level, abstraction plays an important role because students are in the early stages of mastering symbolic representation. However, various studies show that elementary school students' abstraction skills, especially in the subject of perimeter and area of flat shapes, are still relatively low. This is mainly due to learning that is oriented towards the direct provision of formulas without giving students the opportunity to construct conceptual meaning through concrete activities.

This phenomenon is reflected in the results of the 2023 National Assessment (AN), which shows that numeracy indicators related to understanding length and area measurement are among the aspects with the lowest achievements. This finding is consistent with the 2022 PISA report, which found that Indonesian students had difficulty solving problems that required reasoning, visualization, and mathematical generalization skills. ecent research confirms that Indonesian students' numeracy skills particularly in understanding length and area measurement—are among the lowest-performing aspects in both the 2023 National Assessment (AN) and the 2022 PISA report. National data show that average numeracy scores across all education levels remain at the lower-middle range, with significant variation between provinces and school types ("What Are Students' Difficulties in Implementing Mathematical Literacy Skills for Solving PISA-Like Problem?," 2022), Less than 50% of students in some regions meet the minimum competency for numeracy, especially in measurement and geometry content (Mubarkah & Masriyah, 2023; Setiyani et al., 2024).

PISA results consistently place Indonesia near the bottom among participating countries, with a mathematics score of 379 in 2018 and 366 in 2022, well below the OECD average (Mastuti et al., 2023; Mirandah et al., 2025; Nurazizah & Zulkardi, 2022; Nurqamar & Nur, 2022). Fewer than 1% of Indonesian students reach higher proficiency levels (4–6) in mathematical literacy, and most struggle with reasoning, visualization, and generalization—skills essential for solving measurement and geometry problems (Husni & Herman, 2024; Mastuti et al., 2023; Shofa & Hidayah, 2024; Zurriatinnisa, 2024). These difficulties arose because most students only memorized the formulas for perimeter and area without understanding their origins and meanings (Machaba, 2016; Sanfeliz, 2023).

In the context of cognitive development, Piaget explains that elementary school students are in the concrete operational stage, so they need media that can bridge concrete experiences to abstract understanding. The CPA (Concrete–Pictorial–Abstract) model reinforces that understanding mathematical concepts must begin with concrete experiences, followed by pictorial representations, and finally abstract symbols. Interactive Flat Panels (IFPs) are in line with this principle because they provide virtual manipulatives, dynamic visualizations, and interactive activities such as drag-and-drop that allow students to explore flat shapes and measurement concepts directly before moving on to symbolic representations.

Received: August 06, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

The use of Interactive Flat Panels gives students the opportunity to assemble, manipulate, and observe the relationships between parts of flat shapes through virtual manipulatives. For example, with the drag-and-drop feature, students can drag the sides of a shape and rearrange them so that they understand that the perimeter is the sum of all the sides. Through simulations and digital square units, students can also explore the concept of area by covering the surface of a shape with virtual square units. This digital interaction provides a visual and semi-concrete experience that helps students build stronger mental representations and a deeper understanding of concepts.

In addition, the use of manipulative media such as Interactive Flat Panels has the potential to increase student motivation to learn. According to UNESCO (2022), manipulative-based learning increases knowledge retention by up to 40% because it provides an active and meaningful learning experience (Dewanti et al., 2025; Guan et al., 2024). Increased motivation also supports the development of abstraction skills because students are more encouraged to explore and reason (Mubarkah & Masriyah, 2023; Setiyani et al., 2024).

Considering various supporting phenomena and theories, this study was conducted to test the effectiveness of Interactive Flat Panels in improving elementary school students' mathematical abstraction skills. The focus of this study is on the concepts of perimeter and area of flat shapes, which have been one of the main sources of difficulty in basic mathematics learning.

II. Literature Review

Mathematical abstraction is a mental process that enables students to transform concrete experiences into symbolic representations. Schoenfeld (2020) asserts that abstraction is at the core of mathematics learning because it gives students the ability to understand conceptual relationships and make generalizations. At the elementary education level, abstraction is very important in understanding the perimeter and area of flat shapes, because this concept involves the relationship between shape, size, and units of measurement.

Bruner's Theory of Representation (Enactive Iconic Symbolic)

Bruner, (1974) states that the learning process occurs through three stages of mental representation, namely enactive, iconic, and symbolic. The enactive stage refers to learning through direct action; in the context of learning using Interactive Flat Panels (IFPs), this stage occurs when students perform digital manipulations such as sliding, measuring, rotating, and arranging plane figure elements on the screen. The iconic stage emerges when students begin to understand concepts through visual representations in the form of images, colors, animations, and diagrams presented through the IFP display. The symbolic stage occurs when students use formulas, mathematical notation, and generalizations of perimeter and area concepts.

Thus, the IFP is not merely a visual tool, but a complete representational medium that supports Bruner's three stages of representational development. This medium enables a gradual transition that is very important for elementary school students who are still in the concrete operational phase according to Piaget. The integration of digital manipulation (enactive),

Volume 38 No. 11s 2025,
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

screen visualization (iconic), and mathematical symbols (symbolic) helps accelerate the formation of cognitive structures and mathematical abstraction processes, especially in the concepts of perimeter and area of flat shapes.

Dual Coding Theory (Paivio)

Paivio, (1986), through Dual Coding Theory, asserts that learning will be more effective if information is processed through two main channels: verbal and visual. Verbal information in mathematics learning includes teacher instructions, concept explanations, and perimeter or area formulas. Meanwhile, visual information appears in the form of animations, flat shape diagrams, digital manipulative models, and interactive simulations on IFP. Paivio explains that the simultaneous activation of both channels strengthens retention, deepens understanding, and makes it easier for students to build relationships between concepts.

In the context of IFP, this theory is very relevant because the digital platform is capable of combining both types of representation in one learning experience. Interactive digital visualizations support the formation of conceptual images, while verbal explanations reinforce the symbolic structures needed to understand formulas. The integration of both helps students connect the patterns of side relationships in circumference, or the arrangement of area units through digital squares, so that the process of mathematical abstraction occurs more quickly and deeply.

Various studies reveal that elementary school students often experience misconceptions related to the concepts of circumference and area. Oktavia et al., (2025) found that students often have difficulty distinguishing between the two concepts. Students often use the wrong formula because they do not understand the meaning of the concept but only memorize the formula. These findings are reinforced by the results of PISA 2022 and the 2023 National Assessment, which show low numeracy achievement in the measurement domain.

One solution to overcome this difficulty is the use of concrete manipulatives in learning. Bruner, (1974)emphasizes that the learning process must go through three stages: enactive (concrete activities), iconic (image representations), and symbolic (formulas). This approach is known as the CPA model, which has been proven effective in improving mathematical concept understanding. Manipulatives help students understand the meaning of formulas through exploration, not just memorization.

III. Research Methodology

This study employed a quasi-experimental design with a pretest–posttest control group model. Two fifth-grade elementary school classes were selected as the research sample using purposive sampling. The first class served as the experimental group and received instruction using an interactive flat panel, while the second class functioned as the control group and was taught using conventional methods.

The research instrument consisted of a mathematical abstraction ability test that had been validated by experts and tested for reliability using the Cronbach's Alpha coefficient. The study was conducted over four sessions, during which both groups were administered a pretest at the

Volume 38 No. 11s 2025,

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

beginning and a posttest at the end of the treatment. Data were analyzed using a t-test to determine differences in learning gains between the two groups. This analysis aimed to assess the effectiveness of the interactive flat panel in enhancing students' mathematical abstraction ability.

IV. Research Findings

This study involved two groups, each comprising 30 students. The experimental group participated in learning activities using an interactive flat panel, whereas the control group learned through conventional methods. The results indicated a significant improvement in students' mathematical abstraction ability after the treatment.

1. Descriptive Statistics

The study involved 60 students, consisting of 30 students in the experimental group and 30 in the control group. The following summarizes the pretest and posttest scores of mathematical abstraction ability.

Descriptive statistics show that the pretest scores of both groups were relatively similar. The experimental group obtained an average pretest score of 52.40 and a posttest score of 82.73, with a gain score of 30.33. Meanwhile, the control group obtained an average pretest score of 51.67 and a posttest score of 68.20, with a gain score of 16.53. These results indicate that the use of the interactive flat panel yielded an improvement nearly twice that achieved through conventional methods.

Table 1. Descriptive Statistics of Pretest and Posttest

Group	N	Pretest Mean	SD	Posttest Mean	SD	Gain Score
Experimental	30	52.40	9.85	82.73	8.12	30.33
Control	30	51.67	10.21	68.20	9.44	16.53

The table shows that both groups had almost the same initial abilities (the mean difference was only 0.73). However, after the treatment, there was a significant difference in improvement. The gain score of the experimental group was almost double that of the control group. Initial interpretation shows that panel boards had a positive effect on improving abstraction abilities.

2. Distribution of Students' Pretest and Posttest Scores

To clarify the changes in score distribution, the following table shows the ability categories:

Table 2. Distribution of Student Ability Categories

A. Pretest

Category	Value Range	Experiment (n)	Control (n)
High	80–100	0	0

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Volume 38 No. 11s 2025,

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

Medium	60–79	8	7
Low	0–59	22	23

B. Posttest

Category	Value Range	Experiment (n)	Control (n)
High	80–100	21	6
Medium	60–79	9	18
Low	0–59	0	6

In the experimental group, there was a significant shift: there were no longer any low-category students, and 70% were in the high category. In the control group, the shift was still apparent, but smaller.

3. Normality Test

The Kolmogorov-Smirnov test was conducted to ensure the data distribution was normal.

Table 3. Kolmogorov-Smirnov Normality Test Results

Variabel	Group	Sig. (p)	Description
Pretest	Experimental	0.132	Normal
Pretest	Control	0.164	Normal
Posttest	Experimental	0.088	Normal
Posttest	Control	0.112	Normal

All p-values are greater than 0.05, indicating that the data are normally distributed.

The Kolmogorov–Smirnov normality test shows that the data is normally distributed ($p > 0.05$). Levene's homogeneity test also shows that the variances of the two groups are homogeneous ($p = 0.274$). Thus, the parametric t-test can be used.

4. Homogeneity Test

Levene's test is used to examine the similarity of variances between groups.

Variabel	Sig. (p)	Conclusion
Pretest	0.326	Homogeneous
Posttest	0.274	Homogeneous

The variance of both groups was declared homogeneous, so a parametric test was appropriate.

5. Paired t-test (Within Groups)

Received: August 06, 2025

Volume 38 No. 11s 2025,

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

The purpose of this test was to determine whether there was a significant improvement in each group.

Table 5. Paired t-test results

Group	t- Value	Sig. (p)	Conclusion
Experimental	15.864	0.000	Very significant improvement
Control	8.552	0.000	Significant improvement

The experimental group had a t-value twice as high as the control group, indicating a much stronger improvement in abstraction ability. The paired t-test showed that the experimental group experienced a significant improvement ($t = 15.864$, $p = 0.000$), while the control group also improved but to a lesser extent ($t = 8.552$, $p = 0.000$). The independent t-test on the posttest scores showed a significant difference between the two groups ($t = 6.214$, $p = 0.000$).

6. Independent t-test (Intergroup)

Table 6. Results of the Posttest Independent t-test

Variable	t-Value	Sig. (p)	Conclusion
Posttest	6.214	0.000	There is a significant difference

A p-value of 0.000 indicates that the experimental group significantly outperformed the control group.

Interpretation (Cohen, 1988):

- 0.2 = small
- 0.5 = moderate
- 0.8+ = large
- 1.64 = very large effect

This means that interactive flat panel have a very strong impact on students' mathematical abstraction abilities.

8. Analisis Gain Ternormalisasi (Hake's normalized gain)

Tabel 7. Normalized Gain

Group	Pre	Post	Gain (g)	Category
Experimental	52.40	82.73	0.63	High
Control	51.67	68.20	0.33	Medium

Volume 38 No. 11s 2025,

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

The experimental group fell into the high gain category, while the control group fell into the medium gain category.

9. Supporting Qualitative Description

Based on observations:

Experimental Group

a) Students appeared to actively interact through the Interactive Flat Panel, such as dragging and dropping pieces of shapes, measuring lengths using the digital ruler feature, and arranging units of area using virtual objects. These activities show that digital media facilitates direct manipulation of concepts.
b) Discussions among students increased when they tried to explore how the circumference formula was formed by adding the sides displayed on the IFP screen. Interactive visual features helped students quickly verify their understanding.
c) Students are able to explain the concepts of perimeter and area using the representations they previously manipulated on the Interactive Flat Panel media. This indicates a more in-depth mathematical abstraction process.
d) Motivation and engagement in learning increase significantly, as seen in the enthusiasm of students when operating the visual, kinesthetic, and responsive features of the IFP. This media makes learning more interesting and meaningful.

Control Group

a) Learning tends to be passive.

b) Many students still memorize formulas without understanding their origins.

c) Difficulties arise when students are given irregular shapes.

9. Supporting Qualitative Description

The overall results show that interactive flat panel are very effective in improving elementary school students' mathematical abstraction skills, particularly in understanding the concepts of perimeter and area of flat shapes. Digital interactivity, which allows students to manipulate objects directly, such as sliding, measuring, and arranging representations of flat shapes, combined with clear visualizations and conceptual discussions, has been proven to provide a strong cognitive foundation for the formation of mathematical abstraction.

In addition to quantitative results, classroom observations showed that students in the experimental group were more active, enthusiastic, and able to explain concepts well. They also found it easier to understand the relationship between sides, perimeter, and area units. This reinforces that interactive flat panel are effective in improving mathematical abstraction.

III. Discussion

The results of the study indicate that the use of interactive flat panel significantly improves students' mathematical abstraction skills. This can be explained by the CPA (Concrete–Pictorial–Abstract) theory , which emphasizes the importance of concrete experiences as the

Volume 38 No. 11s 2025,
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

basis for forming pictorial and symbolic representations (Iyamuremye & Burns, 2025). Through digital manipulative features such as drag-and-drop, interactive side measurement, and IFP area unit visualization, students can build conceptual bridges from concrete digital experiences to abstract understanding of the perimeter and area of flat shapes (Barbosa & Vale, 2025).

These research findings support Schoenfeld, (2020)view that abstraction develops when students can recognize patterns, relationships, and generalizations. Students in the experimental group were able to find perimeter patterns through activities of pasting and measuring the sides of shapes, as well as understanding the meaning of area through the arrangement of square units (Sanfeliz, 2023). These activities provide a strong foundation for the formation of mathematical generalizations.

The significantly higher improvement in the experimental group also shows that conventional learning is not effective enough in building conceptual understanding. Lecture methods and formula memorization tend to result in shallow procedural understanding. In contrast, interactive flat panel media provides an important multisensory experience for elementary school students. Observations of learning show that social interaction through group discussions helps strengthen students' reasoning, in line with Vygotsky's theory on the importance of the ZPD. Students discuss, examine, and verify ideas with each other, so that their thinking process is more focused. Overall, panel boards support the gradual formation of abstractions in accordance with students' cognitive development stages and are an effective alternative in elementary school mathematics learning.

IV. Conclusion

This study shows that interactive flat panel are effective in improving elementary school students' mathematical abstraction skills in perimeter and area of flat shapes. A significant improvement was seen from the quantitative analysis results, where the experimental group had a much higher gain score than the control group. Interactive flat panel media help students understand concepts through concrete and visual experiences, enabling them to generalize formulas more meaningfully, rather than simply memorizing them. In addition, the use of this media increases student motivation, engagement, and the quality of classroom discussions. Thus, interactive flat panel are worthy of being used as an alternative learning media that supports concept-based mathematics learning at the elementary school level.

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Received: August 06, 2025