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STEM Skewers vs. Flash Cards: Enhancing Conceptual Understanding of Area in Elementary Math Education

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ABSTRACT

Mathematics instruction at the elementary level often struggles to develop students' understanding of area in two-dimensional shapes. To address this challenge, the present study compared the effectiveness of two instructional media, STEM-based skewer sticks and flashcards, in enhancing students' conceptual understanding of the topic. Using a quantitative quasi-experimental design, two groups of fifth-grade students participated in pre-test and post-test assessments. Group A received instructions using skewer sticks, while Group B used flashcards. Both groups demonstrated significant improvement; however, Group A achieved a higher average post-test score (88.93) compared to Group B (83.46). An independent samples t-test confirmed that the difference was statistically significant ($p = 0.017$). The data were normally distributed, as confirmed by the Kolmogorov–Smirnov test, validating the use of parametric analysis. These results suggest that concrete, STEM-integrated learning tools can more effectively support conceptual understanding in geometry topics. From a theoretical perspective, the findings are consistent with constructivist learning theory and dual coding theory, which emphasise the value of multisensory and active engagement in fostering deeper learning. The study emphasises the importance of selecting suitable instructional media to enhance mathematical comprehension at the primary level. Implications for classroom practice include incorporating hands-on materials in teaching abstract concepts. Future research is encouraged to explore long-term retention and implementation across diverse educational settings.

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1. INTRODUCTION

Many elementary students struggle with mathematics due to its abstract nature, which often makes it difficult for them to understand foundational concepts such as area. These difficulties can hinder the development of essential cognitive skills, including

logical reasoning, analysis, and problem-solving. Without adequate understanding at the foundational level, students may continue to face learning barriers as they progress to more complex mathematical topics. Addressing this challenge requires instructional strategies that transform abstract mathematical ideas into tangible, meaningful experiences.

The integration of Science, Technology, Engineering, and Mathematics (STEM) into elementary education has emerged as one such strategy. STEM-based learning encourages hands-on exploration and real-world application, promoting active student engagement [1], [2], [3], [4]. Several studies have demonstrated that STEM approaches can improve students' mathematical literacy and problem-solving skills through contextual and practical tasks [5], [6]. Tools such as skewer sticks—used as concrete manipulatives in STEM classrooms—have also been found to increase both motivation and understanding in basic arithmetic, particularly in topics like division [7], [8]. From a constructivist perspective, this is aligned with the idea that students learn more effectively when they actively construct knowledge through meaningful experiences. Therefore, employing STEM-based tools can be considered a promising approach to enhance students' comprehension of spatial and numerical concepts.

Alongside concrete STEM media, visual tools such as flashcards have long been recognised for their educational value. Grounded in dual coding theory, which emphasises the benefits of combining verbal and visual information, flashcards help reinforce memory and understanding through visual repetition [9], [10], [11], [12], [13]. Research supports their effectiveness in improving learning outcomes in geometry, fractions, and even science-related topics in elementary classrooms [14], [15], [16]. Moreover, flashcards have been found to boost student motivation and engagement, making them a practical choice in many learning environments [17], [18]. Compared to abstract explanations alone, these visual aids allow learners to connect concepts more intuitively and retain information more effectively.

While both concrete STEM media and visual flashcards have demonstrated individual effectiveness in previous studies, direct comparisons between them, particularly in teaching geometric concepts, remain limited. The concept of area, fundamental to understanding plane figures, is often challenging for students to master without the aid of appropriate instructional tools [19], [20], [21], [22], [23]. Given its abstract nature, the teaching area requires instructional media that not only attract students' attention but also facilitate conceptual depth and retention. As such, identifying which media type better supports conceptual understanding can offer valuable guidance for educators seeking to enhance mathematics instruction.

This study aims to compare the effectiveness of STEM-based skewer sticks and flashcard media in improving fifth-grade students' understanding of area concepts at SDN Layungsari 2. By addressing a gap in the existing literature, this research contributes to the development of evidence-based practices for selecting instructional media that enhance student learning. It also provides insight into how different instructional approaches influence cognitive engagement and knowledge construction among young learners. The findings are expected to inform classroom strategies and educational policy focused on improving mathematics outcomes in primary education.

2. METHOD

2.1 Research Design

This study employed a quantitative approach with a quasi-experimental design, specifically the Non-Equivalent Control Group Design [24]. The aim was to compare the effectiveness of two instructional media—STEM skewer sticks and flashcards—in enhancing students' understanding of area concepts in elementary geometry. This design allows comparison between two pre-existing groups that were not randomly assigned but were matched based on similar characteristics. Such a design is commonly used in educational settings where random assignment is impractical, yet group equivalency is still necessary to ensure valid comparisons.

2.2 Participants and Sampling

Participants were fifth-grade students from SDN Layungsari 2, South Bogor District, Bogor City. Two intact classes were selected using purposive sampling to ensure relevance to the research objectives and group homogeneity in terms of prior academic performance. Group A (n = 28) received instruction using STEM skewer sticks, while Group B (n = 26) used flashcards. This sampling method was chosen to ensure that participants had comparable prior knowledge and classroom environments, minimising external variance. Parental consent and school approval were obtained prior to data collection, and the study adhered to ethical research standards as approved by the institutional review process.

2.3 Instruments

The primary research instrument was a mathematics comprehension test focusing on area concepts. It included multiple-choice and short-answer questions covering:

a. Basic understanding of shapes such as squares, rectangles, and triangles
b. Application of formulas for calculating area
c. Problem-solving tasks based on real-world contexts
d. The test's content validity was confirmed through expert review by mathematics educators, while its internal reliability was assessed using Cronbach's Alpha.

The combination of question types aimed to assess both procedural and conceptual knowledge, providing a comprehensive measure of student understanding.

2.3.1 Procedures

The research procedure included three phases:

a. Preparation Phase
   - Development and validation of the test instrument
   - Trial testing with non-participant students to refine the items
   - Selection of equivalent experimental groups based on initial academic records

   This phase ensured that the test instrument was both valid and reliable, and that the comparison groups were academically balanced at the outset.
b. Implementation Phase
   - Pre-tests were administered to both groups to assess baseline understanding.

- Instructional intervention was conducted over four sessions, spanning two weeks.
- Group A received instruction using STEM skewer sticks; Group B used flashcards.
- Both groups received the same duration and content of instruction
- Post-tests were conducted to measure learning gains

Consistency in instructional time and content ensured that any performance differences could be attributed to the media used, rather than instructional disparities.

c. Analysis Phase
   - Calculation of average pre-test and post-test scores for each group
   - Application of normality tests to assess distribution assumptions
   - Independent samples t-tests were used to determine statistical significance between groups

   This phase was critical for evaluating the effectiveness of the intervention and ensuring that statistical assumptions were met before conducting inferential analysis.

2.3.2 Data Analysis

Descriptive and inferential statistical analyses were conducted using SPSS version 25. A significance level of 0.05 was used. Data analysis steps included:

a. Testing for normality using the Kolmogorov–Smirnov test
b. Comparing means with t-tests for both pre- and post-test scores
c. Interpreting p-values to determine the effectiveness of each instructional method

These analyses were selected to ensure robust and accurate Interpretation of learning outcomes across both groups.

2.3.3 Ethical Considerations

This study was conducted under the ethical standards for research. Informed consent was obtained from students' guardians, and permission was secured from the school administration. Participants' confidentiality was strictly maintained, and no identifying information was disclosed in reporting the results. The research protocol was reviewed and approved by the institutional ethics committee.

2.3.4 Success Criteria

Effectiveness was determined by a statistically significant difference in post-test scores between the two groups. A p-value less than 0.05 indicated that one instructional medium was significantly more effective in improving students' understanding of area concepts in elementary geometry. This threshold aligns with standard conventions in educational research for determining meaningful differences in treatment outcomes.

3. RESULTS AND DISCUSSION

3.1 Results Summary

The study involved 54 fifth-grade students divided into two groups:

Table 1. Test results summary

Group	n	Media Used	Pre-test Mean	Post-test Mean	Post-test SD
A	28	STEM Skewer Sticks	38.57	88.93	9.87
B	26	Flashcards	39.23	83.46	10.21

Table 1 above presents data on pre-test and post-test results from two groups of students who used different learning media: STEM Skewer Sticks for Group A and flashcards for Group B. This experimental design aimed to investigate the effectiveness of both instructional media in enhancing students' understanding of area concepts. Group A consists of 28 students with an average pre-test score of 38.57, who experienced a significant increase in their post-test scores, with an average of 88.93 and a standard deviation of 9.87. Meanwhile, Group B, comprising 26 students, had an average pre-test score of 39.23 and a post-test average of 83.46, with a standard deviation of 10.21. Although both groups had relatively comparable initial scores, post-test results showed that the group using STEM Skewer Sticks obtained higher scores and a slightly more consistent distribution of grades compared to the group that used flashcards. These results suggest a notable difference in learning gains between the two instructional approaches, warranting further analysis. To see the difference between the two groups, you can see from Figure 1 below:

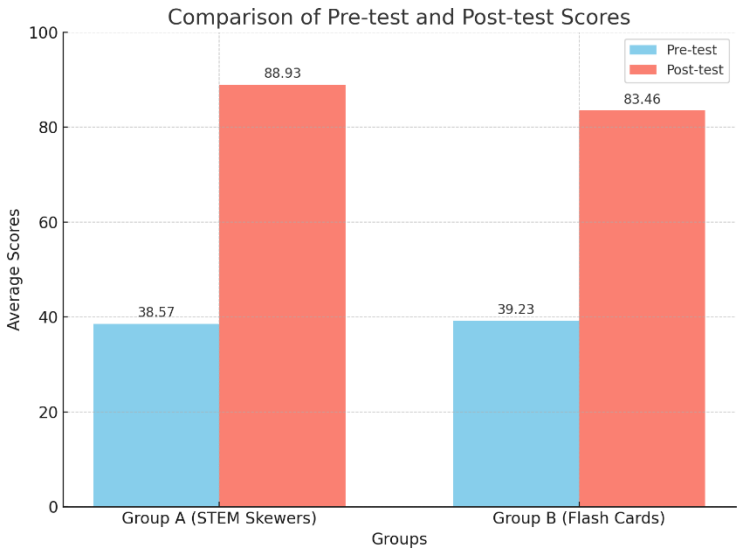

Figure 1. Comparison of Pre-test and Post-test Scores

Figure 1 above illustrates the comparison of the average pre-test and post-test scores for two groups of students using different learning media: STEM Skewer Sticks (Group A) and flashcards (Group B). Initially, both groups had nearly identical pre-test scores, specifically 38.57 for Group A and 39.23 for Group B. However, after the learning intervention, significant improvements were observed in the post-test scores of both

groups. Group A showed the highest average post-test of 88.93, while Group B reached 83.46. This visual representation reinforces the numerical data in Table 1, providing a clear overview of the learning gains achieved through each instructional method. This indicates that the use of STEM Skewer Sticks media has a greater impact on improving learning outcomes compared to the use of flashcards, as reflected in the difference in the average post-test scores between the two groups. Such findings highlight the potential benefits of incorporating hands-on STEM materials in elementary mathematics instruction.

a. Normality Testing (Kolmogorov–Smirnov Test)

Table 2. Normality Testing Results

Group	**K–S Test p-value**	**Interpretation**
Group A Pre-test	0.789	Data are normally distributed
Group B Pre-test	0.861	Data are normally distributed
Group A Post-test	0.927	Data are normally distributed
Group B Post-test	0.701	Data are normally distributed

Interpretation:

Since all p-values are greater than 0.05, it can be concluded that all datasets follow a normal distribution, allowing for parametric statistical analysis. Normality is an essential assumption in conducting independent samples t-tests to ensure the validity and reliability of the results obtained in this study.

b. Independent Samples t-Test

Table 3. Independent Samples t-Test Testing Results

Comparison	t-statistic	p-value	Interpretation
Pre-test A vs B	-2.465	0.017	There is a statistically significant difference
Post-test A vs B	2.562	0.013	There is a statistically significant difference.

Note:

A p-value less than 0.05 indicates that the differences in mean scores between groups A and B are statistically significant, both before and after the intervention. These statistical results suggest that while the groups differed slightly at baseline, the post-test difference remained significant, confirming the superior effect of the STEM Skewer Sticks intervention.

c. Interpretation of p-values and Instructional Effectiveness

Although a significant difference was already present in the pre-test scores, the significantly higher post-test scores in Group A suggest that both instructional methods were effective in improving learning outcomes. However, the group that used STEM Skewer Sticks (Group A) demonstrated a greater improvement, with a significantly higher post-test mean score than the Flashcards group. This indicates that the use of hands-on, concrete STEM-based materials may be more effective in enhancing students' conceptual understanding compared to traditional flashcard methods. The incorporation of STEM

Skewer Sticks appears to facilitate deeper engagement and active learning experiences, leading to improved performance.

The results of the study indicate that both instructional methods—STEM Skewer Sticks and flashcards—were effective in improving students' understanding of area concepts, as reflected in the significant increase in post-test scores for both groups. Statistical analysis using the Kolmogorov–Smirnov test confirmed that the data were normally distributed, and independent samples t-tests showed a significant difference in both pre-test ($p = 0.017$) and post-test ($p = 0.013$) scores between the groups. Notably, students in the STEM Skewer Sticks group achieved significantly higher post-test scores, suggesting that this method was more effective than flashcards. This effectiveness may be attributed to the kinesthetic and multisensory nature of the STEM activity, where students physically constructed geometric shapes and measured areas using skewers. According to constructivist learning theory, learners develop deeper conceptual understanding when they actively interact with learning materials. This aligns with educational research advocating for active learning strategies to enhance mathematics achievement among elementary students.

Furthermore, dual coding theory supports the idea that combining visual, verbal, and tactile experiences enhances memory retention and comprehension. In contrast, while flashcards helped improve students' performance, their reliance on visual-textual cues may have fostered more surface-level recall. Therefore, the difference in post-test performance likely reflects not only effectiveness in boosting scores but also the depth and durability of understanding fostered by each instructional approach. Overall, the findings offer valuable implications for teachers and curriculum developers to integrate concrete, STEM-based instructional tools in elementary classrooms, promoting meaningful learning and long-term retention.

3.2 Discussion

The results of this study show that both STEM media, Skewer Sticks and flashcards, are equally effective in improving students' understanding of the broad concept of flat building. This is evidenced by a significant increase in post-test scores in both groups after the learning intervention. Statistical analysis showed that the data were distributed normally and there was a statistically significant difference between the pre-test and post-test scores of each group, with a p-value < 0.05. The group that used the STEM Skewer Sticks media obtained a higher average post-test score compared to the flashcard group, suggesting that the concrete media had a more substantial influence on understanding spatial concepts.

The effectiveness of STEM Skewer Sticks in this study can be explained through constructivist learning theory, which emphasises that students actively build knowledge through hands-on experience. In this context, the students' physical involvement in constructing flat builds using skewers allows them to internalise broad concepts more deeply, both procedurally and conceptually. Additionally, dual coding theory supports these findings by explaining that incorporating visual, verbal, and tactile information can significantly enhance students' memory and comprehension. In contrast, while flashcards

have been shown to help improve scores, they primarily play a role in strengthening short-term memory through visual and textual repetition, which is likely to result in more superficial comprehension.

The findings of this study are in line with previous studies that show that STEM-based concrete media can increase students' motivation and understanding in mathematics learning [7], [8], as well as that flashcards are effective in supporting students' memory and engagement [14], [17]. However, a significant contribution of this study is the direct comparison between the two types of media in the context of flat building broad materials. By empirically comparing these two approaches, this study provides evidence that concrete experiential learning is superior in encouraging deep conceptual understanding, especially in materials that are abstract and require spatial visualisation [11], [12], [13], [25].

Although the results show strong findings, the study has some limitations that need to be looked at. The study was conducted in only one school with a limited sample size, so the generalizability of the results to the broader population still needs further investigation. In addition, the short duration of the intervention (four sessions in two weeks) has not been able to demonstrate the long-term durability of comprehension. Other factors, such as teachers' teaching styles and students' backgrounds that are not fully controlled, can also affect the results. Therefore, follow-up research is recommended to involve more schools, extend the duration of interventions, and explore other learning media, including interactive digital media, to provide a more comprehensive guide to improving the quality of mathematics learning in primary schools.

4. CONCLUSION

This study aimed to compare the effectiveness of two instructional media—STEM skewer sticks and flashcards—in enhancing elementary students' understanding of area concepts. The results demonstrated that both media contributed positively to students' learning outcomes. However, the group that used STEM skewer sticks achieved significantly higher post-test scores, indicating that concrete, hands-on instructional tools provide a greater advantage in facilitating a conceptual understanding of geometric topics, particularly in measuring area.

The findings highlight the pedagogical value of manipulatives in early mathematics education, supporting theories such as constructivism and dual coding. Concrete materials, such as, allow students to engage in active, multisensory learning experiences that bridge the gap between abstract mathematical concepts and real-world applications. This approach fosters not only cognitive development but also motivation and engagement in the learning process.

Nevertheless, several limitations of this study should be acknowledged. The sample was limited to two intact classes from a single school, which may affect the generalizability of the findings. The intervention was conducted over a short duration (two weeks), and the study did not assess long-term retention or delayed learning effects. Additionally, potential external variables, such as teaching style and students' prior familiarity with instructional media, were not controlled.

Future research is recommended to extend the scope of investigation by involving larger, more diverse samples across multiple educational settings. Longitudinal studies could help assess the sustained impact of STEM-based media on students' mathematical development. Furthermore, comparative studies incorporating digital and hybrid instructional tools may provide insights into how traditional manipulatives can be effectively integrated with modern technologies to enhance learning outcomes.

For educators and curriculum designers, this study suggests that low-cost, accessible, and practical tools, such as STEM skewer sticks, can serve as an effective medium to support geometry instruction in elementary classrooms. Especially for abstract concepts such as area, hands-on strategies may play a crucial role in making mathematics more engaging, meaningful, and understandable for young learners.

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