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Effectiveness of Transparent Concrete Media for Geometry Learning in Improving Junior High School Students' Understanding of Surface Area

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ABSTRACT

Mastery of the concept of surface area in solid figures remains a challenge for junior high school students, particularly in linking three-dimensional representations with their corresponding nets. This study aimed to examine the effectiveness of transparent solid figures as concrete learning media in improving students' understanding of surface area concepts. Conducted at SMPIT Al Mubarok, Serang City, during the 2025/2026 academic year, the study employed a quantitative method using a one-group pretest–posttest experimental design. Thirty ninth-grade students were selected through accidental sampling based on accessibility and availability. A concept comprehension test was administered before and after the treatment, and data were analyzed descriptively and inferentially. Results indicated that students' surface-area comprehension improved significantly following the use of transparent concrete instructional media. The mean pretest score of 81.43 increased to 100 on the posttest. The Wilcoxon Signed-Rank Test revealed a significance value of 0.000 (<0.05), and the N-Gain score of 1.00 was categorized as high, confirming that transparent solid media were highly effective in enhancing students' conceptual understanding of surface area.

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1. INTRODUCTION

21st-century education requires students to master competencies that extend beyond factual knowledge, emphasizing critical thinking, creativity, conceptual understanding, and the ability to apply knowledge in real-life contexts [1]. In mathematics learning, conceptual mastery is measured not only through computational skills but also through the depth of students' understanding of the meaning behind each mathematical procedure [2]. Ideally, mathematics instruction should emphasize thinking processes that help students discover relationships between concepts rather than focusing solely on final calculation results [3].

Geometry, as a key branch of mathematics, plays a crucial role in developing visual and conceptual thinking skills. Through geometry learning, students are encouraged to understand the relationships between shapes and space and to enhance their spatial visualization abilities [4]. However, studies consistently show that students often face difficulties when learning geometric concepts, especially topics related to three-dimensional figures and their surface areas. These challenges arise because students struggle to visualize 3D objects abstractly [5]. Procedural and symbolic learning approaches also contribute to students' tendency to memorize formulas without understanding their conceptual foundations [6]. As a result, they frequently develop misconceptions when asked to explain the origin of surface area formulas or relate them to nets of solid figures [7]. Therefore, appropriate learning media are needed to provide students with concrete experiences that support the construction of clear conceptual understanding.

Constructivism posits that learners actively build knowledge through interaction with their environment and through direct experiences [8]. In the context of geometry learning, this theory can be implemented by incorporating tangible media that allow students to manipulate objects, examine relationships among the components of geometric solids, and derive surface-area concepts through hands-on exploration [9]. Concrete media function as a link connecting real-life experiences with abstract mathematical concepts, thereby enhancing students’ conceptual understanding [10].

Evidence from previous research indicates that incorporating concrete learning media into geometry lessons has a positive impact on students’ motivation, interest, and conceptual mastery [11]. One relevant development is transparent concrete spatial media, which has been declared valid and practical in previous development studies. This media is designed from transparent acrylic material that can be opened and rearranged, allowing students to directly see the relationship between the constituent sides and the surface area [12]. Unlike previous studies using opaque or virtual media, this study introduces transparent acrylic-based manipulatives that allow students to visualize the internal structures of 3D solids directly, offering a more comprehensive spatial learning experience.

This study aims to evaluate the effectiveness of transparent concrete geometry media in improving junior high school students’ conceptual understanding of surface area. The findings are expected to reinforce the theoretical foundations of experiential learning and provide practical guidance for mathematics teachers on using manipulative materials to create learning environments that are more interactive and conducive to deeper understanding.

2. METHOD

This study employed a quantitative method using a one-group pretest–posttest experimental design [13]. This design was selected to evaluate the effectiveness of transparent concrete media in enhancing students’ understanding of surface area concepts by comparing their scores before and after the intervention [14]. The one-group pretest–posttest design is often employed in educational research to evaluate the improvement in learning outcomes within a single group, without a comparison group [15].

The research procedure consisted of three main stages. The initial phase involved administering a pretest to identify students' baseline understanding of the surface area of solid figures. The second phase consisted of a treatment session during which students participated in learning activities using transparent concrete spatial models (such as cubes, blocks, prisms, pyramids, cylinders, and cones) made from acrylic. These activities allowed students to explore and connect three-dimensional forms with their corresponding nets. The final phase included a posttest designed to evaluate the improvement in students' conceptual comprehension after the intervention. Two validators, a mathematics education lecturer and a mathematics teacher, reviewed the content validity and appropriateness of the concrete media visualization used. Table 1 presents the research design.

Table 1. One-Group Pretest–Posttest Experimental Design

Pretest	Treatment	Posttest
O_1	X	O_2

Description:

O_1 = Pre-intervention test result

X = Learning using transparent concrete spatial media

O_2 = Post-intervention test result

The research was carried out in the even semester of the 2025/2026 academic year at SMP IT Al Mubarok in Serang City, Banten. The research population consisted of all ninth-grade students at the school, and a sample of 30 was selected via convenience sampling. This technique was selected for its practicality in terms of accessibility, participant availability, and classroom teachers' willingness to support the learning intervention. The selection aimed to ensure smooth coordination during the treatment process and to reflect the typical mathematics learning situation at the junior high school level.

Data analysis employed both descriptive and inferential statistical techniques. The descriptive analysis summarized the score distribution, sample size, minimum and maximum scores, mean, and standard deviation. Before conducting the inferential analysis, the pretest and posttest scores were assessed for normality using the Shapiro–Wilk test [16]. If the data met the normality assumption (sig. > 0.05), the analysis proceeded with a paired t-test to assess the significance of the difference between the pretest and posttest scores [17]. If the data did not meet the normality assumption ($p \leq 0.05$), the Wilcoxon Signed-Rank test was employed as the nonparametric procedure [18]. The hypothesis for this study was stated as follows:

H_a: The use of transparent concrete media is effective in improving students' understanding of surface area concepts.

H_0: The use of transparent concrete media is not effective in improving students' understanding of surface area concepts.

Interpretation is conducted by comparing the obtained significance value with the 0.05 significance level. If the significance value is < 0.05, it indicates a meaningful difference between the pretest and posttest scores, leading to the acceptance of the alternative hypothesis (H_a) and the rejection of the null hypothesis (H_0). Conversely, if the significance value is ≥ 0.05, it shows that no significant difference exists; therefore, the null hypothesis (H_0) is accepted, and the alternative hypothesis (H_a) is rejected [19]. The effectiveness of the treatment is further examined by calculating the Normalised Gain (N-Gain), which is determined using the following formula:

$$g = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \tag{1}$$

The classification of N-Gain values used to interpret the level of improvement is presented in Table 2.

Table 2. Classification of N-Gain

N-Gain Value	Criteria
$g \geq 0{,}70$	High
$0{,}30 \leq g < 0{,}70$	Medium
$g < 0{,}30$	Low

3. RESULTS AND DISCUSSION

3.1. Results

This study investigated the effectiveness of transparent concrete media in enhancing students' comprehension of surface-area concepts. Data on student learning outcomes were collected through pretest and posttest assessments administered to 30 participants. Overall, the results indicate a substantial improvement in students' understanding following the intervention, as shown through descriptive, normality, and inferential analyses. A summary of the descriptive statistics for both tests is presented in Table 3.

Table 3. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Pretest	30	70	90	81.43	8.645	74.737
Posttest	30	100	100	100	0	0

According to Table 3, the average pretest score of students was 81.43 with a standard deviation of 8.645, while the average posttest score reached 100 with a standard deviation of 0, indicating no variation in the final results. This suggests that all students achieved maximum scores after receiving learning treatment using transparent concrete media. Thus, the descriptive analysis indicates a strong improvement in learning outcomes following the intervention.

Prior to conducting inferential analysis on the pretest and posttest scores, a normality assessment was performed using the Shapiro-Wilk test, considering that the total number of participants was fewer than 50. The outcomes of this normality test are summarized in Table 4.

Table 4. Normality Test Results for Pretest and Posttest

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre Test	204	30	.003	.842	30	.000
Post Test	.313	30	.000	.754	30	.000

a Lilliefors Significance Correction

Based on the results in Table 4, it is evident that the significance values (Sig.) for both the pretest and posttest are 0.000, which is less than 0.05. This means that the data on student learning outcomes before and after the treatment are not normally distributed. Consequently, a nonparametric Wilcoxon Signed-Rank Test was employed to examine the difference between pretest and posttest scores rather than a parametric paired t-test. The Wilcoxon test results are shown in Table 5.

Table 5. Wilcoxon Signed-Rank Test Results

Ranks

		N	Mean Rank	Sum of Ranks
Posttest - Pretest	Negative Ranks	0[a]	.00	.00
	Positive Ranks	30[b]	15.50	465.00
	Ties	0[c]		
	Total	30		

a. posttest < pretest
b. Posttest > Pretest
c. Posttest = Pretest

Test Statistics[a]

	Posttest - Pretest
Z	-4.819[b]
Asymp. Sig. (2-tailed)	<.000

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

Based on the Wilcoxon test results in Table 5, a Z value of -4.819 was obtained with a significance value ($p < 0.001$). This finding confirms a significant difference between the students' pretest and posttest scores. Every student showed higher scores after instruction with transparent concrete media, indicating that the media effectively enhanced their understanding of surface area concepts.

The N-Gain score was computed to assess the extent of students' learning improvement, and the results are summarized in Table 6.

Table 6. The N-Gain score results

Respond (1-30)	Spre	SPost	Score N-Gain
Mean	81.43	100	1.00

As shown in the results presented in Table 6, the mean N-Gain score was 1.00, which is categorized as high according to the interpretation standards outlined in Table 2. This result suggests that incorporating transparent solid media greatly improves students' comprehension of surface area in three-dimensional shapes. All students showed optimal

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learning improvement, achieving maximum scores after the application of this learning media.

3.2. Discussion

Cognitive Effect

The results of this study indicate that transparent concrete media are highly effective in enhancing the understanding of grade IX students of the surface area of solid figures at Al Mubarok Islamic Junior High School. Analytical findings showed a rise in students' mean performance, improving from a pretest score of 81,43 to a posttest score of 100. The Wilcoxon Signed-Rank Test yielded a significance value of 0.000 (< 0.05), indicating that the difference between the pretest and posttest scores was statistically significant. These results confirm that transparent concrete geometry media had a measurable and meaningful impact on students' conceptual understanding of surface area concepts [16].

Constructivist Validation

The use of concrete media in mathematics instruction enables students to participate actively through hands-on learning. Through transparent models, students can directly observe the shapes, dimensions, and relationships among the faces of three-dimensional objects, enabling deeper comprehension of surface-area concepts [17]. This aligns with Bruner's theory, which emphasizes the progression from enactive to iconic and symbolic representation when learning abstract mathematical ideas [18]. In this study, students naturally progressed from concrete manipulation to symbolic generalization through the use of transparent media.

Support from Previous Research

The effectiveness of transparent concrete media is further supported by previous studies, which show that manipulative and concrete instructional tools significantly enhance students' conceptual mastery and spatial reasoning in geometry [16]. These media facilitate students' visualization of planar relationships and volumetric structures within three-dimensional figures [17], reinforcing the cognitive benefits observed in this study.

Spatial Visualization Enhancement

Transparent spatial models help students overcome common challenges related to visualizing complex geometric structures. The models enable students to visualize interior and hidden surfaces, facilitating their understanding that surface area is determined by summing all visible and non-visible faces [19]. Such visual access strengthens spatial reasoning and enhances students' ability to interpret the relationships among surfaces in three-dimensional objects [19], [20].

Learning Gain Analysis

The mean N-Gain score of 1.00 falls within the high category, indicating that the improvement in student understanding achieved through the use of transparent concrete media was optimal. These findings are consistent with earlier research demonstrating that the use of concrete instructional media significantly increases motivation and improves learning outcomes in geometry [21], [22].

Affective Engagement

Beyond cognitive outcomes, the use of transparent concrete media also contributed to students' affective development. Students exhibited greater enthusiasm, motivation, and active participation during the learning process. The engaging and interactive nature of the media fostered a positive learning environment, increasing focus and involvement [23]. This aligns with Piaget's perspective that meaningful learning arises from direct interaction with concrete objects [24], and is further supported by Dale's cone of experience, which emphasizes the importance of direct experience in enhancing the comprehension of abstract concepts [25].

Pedagogical Implications

These findings suggest that integrating transparent media into geometry learning aligns with 21st-century learning principles by supporting inquiry-based instruction, critical thinking, collaboration, and student-centered practices. The media's visual and tactile characteristics make it highly relevant for contemporary mathematics classrooms seeking to enhance conceptual understanding through active learning.

Scalability and Digital Adaptation

Given its effectiveness, this innovation has strong potential to be scaled through teacher professional development, school-based workshops, and integration into instructional modules. Furthermore, transparent spatial media can be digitalized, such as through augmented reality (AR) platforms or interactive 3D applications, to broaden access and support implementation in blended and virtual learning environments.

4. CONCLUSION

This study aimed to evaluate the effectiveness of transparent concrete geometry media in enhancing junior high school students' conceptual understanding of surface area. The findings demonstrated a substantial improvement in student learning outcomes, as reflected in the increase in the mean score from 81.43 (pretest) to 100 (Posttest). This gain was statistically significant ($p = 0.000 < 0.05$) and supported by a high N-Gain value of 1.00, indicating a strong conceptual improvement. Conceptually, the transparent media successfully helped students connect abstract geometric ideas with their concrete representations, enabling deeper understanding through direct exploration.

Pedagogically, the use of transparent acrylic-based manipulatives serves as an effective instructional strategy in geometry learning. The media not only improved cognitive outcomes but also stimulated higher student motivation, participation, and engagement throughout the learning process. These results align with constructivist learning principles, showing that hands-on and visual experiences play a crucial role in strengthening students' understanding of abstract mathematical concepts. Therefore, this media can be considered a practical and beneficial tool for teachers seeking to implement active, contextual, and student-centered geometry instruction.

Despite its promising results, this study is limited by its implementation in a single school context and its focus on a single geometry topic: the surface area of solid figures. These limitations restrict the generalizability of the findings. Future research is recommended to examine the effectiveness of transparent geometry media across diverse schools, grade levels, and mathematical topics such as volume, nets, or geometric transformations. Longitudinal studies are also needed to investigate the long-term impact on conceptual retention and students' visual-spatial abilities.

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