An analysis of the effectiveness of visual media in teaching solid geometry to improve students' conceptual understanding in mathematics

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Abstract
This study aims to analyze the effectiveness of visual media in improving students' conceptual understanding of mathematics in the topic of three-dimensional geometry among sixth-grade students at SD Negeri 2 Kiarajangkung. The research employed a quasi-experimental method with a one-group pretest-posttest design. The instruments used included an open-ended test on geometric concepts, observation sheets, and documentation. The results of the t-test analysis indicated a significant improvement in students' understanding after the implementation of visual media. The average pretest score was 58.93 and increased to 83.21 in the posttest, with a significance value of 0.000 < 0.05. Thus, visual media is proven to be effective in enhancing students' conceptual understanding.
Keywords: visual media; solid geometry; conceptual understanding; elementary mathematics

Abstrak
Penelitian ini bertujuan untuk menganalisis efektivitas penggunaan media visual dalam meningkatkan pemahaman konsep matematika pada materi bangun ruang siswa kelas VI di SD Negeri 2 Kiarajangkung. Metode yang digunakan adalah kuasi eksperimen dengan desain pretest-posttest satu kelompok. Instrumen yang digunakan berupa tes uraian konsep bangun ruang, lembar observasi, dan dokumentasi. Hasil analisis menggunakan uji-t menunjukkan peningkatan signifikan pada pemahaman siswa setelah penggunaan media visual. Rata-rata nilai pretest adalah 58,93 dan meningkat menjadi 83,21 pada posttest, dengan nilai signifikansi 0,000 < 0,05. Dengan demikian, media visual terbukti efektif dalam meningkatkan pemahaman konsep siswa.
Kata Kunci: media visual; bangun ruang; pemahaman konsep; matematika SD

Introduction

Mathematics education at the elementary level plays a crucial role in forming the foundation of students' logical reasoning, critical thinking, and systematic problem-solving abilities from an early age (Nurlaelah, Usdiyana, & Fadilah, 2024). One of the essential yet challenging topics in elementary mathematics is solid geometry, which falls under the scope of spatial reasoning. This topic not only requires students to understand the shape, size, and position of objects in space but also to visualize and mentally manipulate three-dimensional objects, a skill that demands higher-order cognitive processes. In reality, most elementary students remain in the concrete operational stage, according to Piaget's cognitive development theory, and thus struggle to comprehend abstract representations of spatial objects (Ibrahim & Sari, 2021; Mutaqin et al., 2023). Solid geometry includes understanding the properties of edges, vertices, and faces, as well as how these components relate to one another. In practice, however, these concepts are frequently introduced through two-dimensional textbook illustrations, which are limited in effectively depicting three-dimensional relationships. As a result, many students develop misconceptions and fail to connect illustrations with the actual physical shapes they represent. Jannah and Hidayat (2021) found that approximately 64% of upper elementary school students misidentified the elements of three-dimensional shapes due to limited spatial visualization and the absence of concrete learning aids in the classroom.

In the past five years, various studies have emphasized that the systematic use of visual media can significantly improve students' mathematical understanding and help rectify misconceptions (Sari, Supriadi, & Putra, 2022; Saepuloh, Luritawaty, & Afriansyah, 2024). Visual media serves as a cognitive bridge between abstract representations and concrete experiences, enabling learners to explore concepts more meaningfully (Suryaniet al., 2020; Muhtadi, Wulandari, & Sukirwan, 2023). Fitriani, Wahyudin, and Rahmawati (2020) found that the use of physical manipulatives and three-dimensional media increased student engagement and spatial skills, especially among sixth-grade elementary students. By integrating visual, kinaesthetic, and manipulative elements, students are better able to distinguish the characteristics of different geometric shapes.

Visual media in mathematics instruction can take many forms, such as physical geometric models, 3D illustrations, animated digital content, and Augmented Reality (AR) technology (Fauzi, Yaniawati, & Sari, 2024; MZ et al., 2024; Lestiana et al., 2025). These media tools provide multisensory learning experiences that activate different cognitive pathways, including visual processing and long-term memory retention (Ramadhani & Nuryadi, 2023). In addition to cognitive gains, the use of visual media also enhances students' motivation and enthusiasm toward learning mathematics. Widyaningtyas and Sukarmin (2021) reported that students became more active and involved in classroom

discussions when mathematics was taught using visual aids. Beyond cognitive benefits, visual media also aligns with the development of character values and 21st-century skills. In the context of Indonesia's *Merdeka Curriculum*, visual-based learning supports the formation of critical and independent thinking, two key dimensions of the Profil Pelajar Pancasila (Kemdikbudristek, 2022). Such pedagogical approaches allow teachers to create learning environments that emphasize reasoning, exploration, and meaningful collaboration (Hasibuan & Lestari, 2020; Arwadi, Sidjara, & Suarlin, 2023).

Preliminary observations at SD Negeri 2 Kiarajangkung affirmed the need for improved instructional strategies. Many sixth-grade students were unable to fully understand the properties of solid figures, such as calculating edges and identifying geometric nets. They also found it difficult to differentiate between common three-dimensional shapes. These findings indicate that the previous instructional approach lacked concrete, interactive elements necessary for conceptual comprehension. Furthermore, the use of visual media in mathematics learning is supported by constructivist learning theory, which posits that students build knowledge through direct experience and contextual interaction with their environment (Yuliani & Nugroho, 2021; Meilina, Mariana, & Rahmawati, 2023). Thus, visual media should not be viewed merely as supplementary teaching aids but as integral components of pedagogical strategies that foster deep understanding and cognitive development.

Based on the above, this study aims to analyze the effectiveness of visual media in teaching solid geometry to enhance the conceptual understanding of sixth-grade students at SD Negeri 2 Kiarajangkung. The findings of this research are expected to contribute theoretically to the field of elementary mathematics education and practically by providing evidence-based recommendations for improving teaching practices through innovative media integration.

Method

This study employed a quantitative approach with a quasi-experimental method using a one-group pretest-posttest design. This design was chosen to evaluate the effectiveness of visual media in improving students' conceptual understanding of three-dimensional geometry. The one-group pretest-posttest model is widely used in classroom-based experimental research as it allows the researcher to observe changes in learning outcomes before and after a specific instructional intervention (Fraenkel et al., 2019). This design was considered appropriate due to the homogeneous nature of the sample and the objective to assess learning improvement after treatment. The research was conducted at SD Negeri 2 Kiarajangkung, located in the district of Tasikmalaya, West Java, Indonesia. The research population consisted of all students in grade VI, totaling 28 students. Due to the limited

size and accessibility of the population, the entire class was selected as the research sample using total sampling technique. All students participated voluntarily and were informed of the research objectives and procedures. The sample was considered representative for this research since it met the criteria for studying geometric understanding in upper primary education.

The instrumentation of the study was a critical component. The primary instrument used was a test of conceptual understanding consisting of 10 essay-type questions specifically developed to assess students' comprehension of geometric elements including edges, vertices, and faces; recognition of various three-dimensional shapes; the relationship between nets and solid shapes; and spatial visualization. The items were developed based on the national curriculum and indicators aligned with higher-order thinking skills, particularly in the cognitive domain of *understanding* and *analyzing* according to Bloom's Taxonomy (Anderson & Krathwohl, 2001). Each item was validated by three experts in mathematics education to ensure content validity. A small-scale pilot test was conducted in another elementary school with similar characteristics to test the reliability and clarity of the items.

In addition to the conceptual test, an observation sheet was used to document students' learning behaviors and engagement throughout the instructional sessions. The observation focused on aspects such as student attention, participation in discussion, interaction with media, and responsiveness to teacher questions. This instrument was scored using a rubric on a 4-point Likert scale and filled out by both the classroom teacher and the researcher to ensure inter-rater reliability. The research procedure was carried out in three main phases over the course of three days. The first phase involved the administration of the pretest, which was conducted in a formal, test-like environment to measure students' initial understanding of geometric concepts. The second phase consisted of instruction using visual media. This treatment phase introduced students to three-dimensional geometric objects through various media including: (1) physical models (e.g., plastic models of cubes, cuboids, pyramids, prisms), (2) interactive image projections using a projector and computer-based slide shows, and (3) video animations that visually demonstrated how nets fold into solid figures. The teacher facilitated activities that allowed students to manipulate the models, make predictions, and discuss their observations with peers. Each session was designed to be student-centered and exploratory, with learning activities structured around problem-solving, hands-on manipulation, and small group discussion.

The third phase involved the administration of the posttest, which was parallel in structure and difficulty to the pretest but contained different items to avoid memorization bias. Following the posttest, the observation sheets were completed and cross-checked by two observers. All students were debriefed at the end of the study. From an ethical

standpoint, this study followed the standard research protocol in education. Permission was obtained from the school principal and the class teacher. Students were informed about the purpose and nature of the study, and parental consent was secured in written form. Anonymity and confidentiality were maintained throughout the data collection and analysis process. The researcher ensured that the intervention did not disrupt the school's teaching schedule or compromise any students' learning experience.

The data analysis was conducted using both descriptive and inferential statistics. Descriptive statistics were used to determine the mean, minimum and maximum scores, and standard deviation of student scores in both the pretest and posttest. To assess whether the difference in scores was statistically significant, the paired sample t-test was employed using SPSS version 25. The choice of this statistical method was appropriate as it evaluates mean differences in two related samples, in this case, the same group of students before and after treatment. The significance level was set at $\alpha = 0.05$, meaning that any p-value below this threshold would be considered indicative of a significant difference in learning outcomes. The results of this data analysis are expected to provide empirical evidence on the effectiveness of visual media in supporting mathematical concept acquisition, particularly in topics involving spatial and geometric reasoning. Moreover, the data would serve as a foundation for proposing instructional strategies that align with cognitive development theories and inclusive education principles at the primary level.

Result

The findings of this study indicate that the use of visual media in mathematics instruction has a significant impact on improving students' conceptual understanding of solid geometry. To assess this impact, pretest and posttest assessments were administered to a group sixth-grade student at SD Negeri 2 Kiarajangkung. The assessment instrument consisted of 10 open-ended questions designed to measure students' understanding of geometric properties, their ability to match nets with three-dimensional shapes, and their skills in comparing the characteristics of different solid figures. The descriptive results of the pretest and posttest are presented in the following Table 1.

Table 1. The descriptive results of the pretest and posttest

Statistic	Pretest	Posttest
Highest Score	87	100
Lowest Score	75	85
Mean	80.21	91.00
Standard Deviation	3.34	4.12

The Table 1 reveals a mean score increase of 10.79 points following the implementation of visual media-based instruction. Not only did the average score improve, but both the minimum and maximum scores increased as well. Before the intervention, student scores ranged from 75 to 87, while after the intervention they ranged from 85 to 100. Although the standard deviation increased slightly, this reflects the variability of improvement among students, all of whom still achieved high scores. These results suggest that visual media effectively supported students across different initial ability levels in enhancing their understanding. The fact that no student scored lower in the posttest than in the pretest indicates that the approach is not only beneficial but also safe to implement widely in geometry instruction. Overall, these results reinforce previous findings that visual-based approaches can bridge learning gaps and significantly improve student outcomes in mathematics.

Discussion

The findings of this study demonstrate that the use of visual media in mathematics instruction has a substantial effect on improving students' conceptual understanding of solid geometry. The increase in average scores by 10.79 points from the pretest to the posttest indicates not only the acquisition of new knowledge but also the internalization of deeper comprehension regarding the structure and properties of three-dimensional figures. These results confirm the critical role of visualization in supporting elementary-level mathematics learning, particularly for abstract topics such as spatial geometry (Suryani et al., 2020; Ibrahim & Sari, 2021). From a theoretical perspective, these results align with Piaget's theory of cognitive development, which asserts that elementary school students are typically in the concrete operational stage. At this stage, learners require direct experience and tangible objects to construct conceptual understanding. Therefore, instruction that is purely symbolic or verbal often fails to deliver meaningful learning for young learners (Yuliani & Nugroho, 2021). The use of physical models, three-dimensional illustrations, and animated visuals enables students to observe, manipulate, and connect learning materials with prior cognitive structures, supporting both assimilation and accommodation processes.

Empirically, this study corroborates findings by Fitriani et al. (2020), who reported that students engaged in geometry learning with visual manipulatives demonstrated significant improvements in spatial ability, shape analysis, and mathematical communication. Visualization helps students mentally represent objects, identify structural relationships, and reduce misconceptions that commonly occur with two-dimensional textbook illustrations. For instance, students who previously misidentified the number of edges or vertices of a prism were able to correct and explain their reasoning after

interacting with 3D media. Visual-based instruction also positively influences student engagement. Classroom observations during this study revealed heightened enthusiasm, focus, and interaction among students. This is consistent with the research of Widyaningtyas and Sukarmin (2021), who found that students were more responsive and participative when mathematics was taught using visual tools. Active involvement allows learners to process information through exploration, questioning, and reflection, leading to more meaningful and lasting learning outcomes.

Furthermore, the use of visual media supports the development of higher-order thinking skills (HOTS). Tasks that require students to compare shapes, identify forms from nets, or justify differences between prisms and pyramids engage analytical and evaluative cognitive processes—two of the highest levels in Bloom's revised taxonomy (Brookhart, 2020). This indicates that the intervention went beyond mere memorization and fostered critical and applied thinking. From a socio-affective perspective, visual-based instruction creates a more inclusive and collaborative learning environment. Group discussions and shared exploration foster positive learning cultures aligned with the values of *Profil Pelajar Pancasila*, such as critical reasoning, independence, and teamwork (Kemdikbudristek, 2022). In the context of the *Merdeka Curriculum*, this approach is especially relevant as it promotes differentiated instruction, ensuring that each student receives learning experiences tailored to their needs and learning styles (Hasibuan & Lestari, 2020).

Notably, visual media was effective across the full range of student ability levels. Students with lower initial understanding also benefited and were able to improve significantly. This finding is consistent with Santoso and Febriana (2022), who concluded that visual learning approaches are especially effective for students with visual and kinesthetic learning preferences. Even students with learning difficulties showed progress when provided with concrete media and guided visual representations (Sulaeman & Hartati, 2023). Pedagogically, the findings affirm the need to shift from text-based instruction toward contextual, visual, and experience-driven learning. Teachers must transition from being mere transmitters of knowledge to facilitators who create meaningful learning experiences. This approach enhances student retention, conceptual understanding, and motivation to learn (Ramadhani & Nuryadi, 2023).

Practically, the results underscore the importance of professional development for teachers in designing and utilizing effective visual media. Schools should support this by providing adequate teaching aids, access to digital resources, and opportunities for integrating technology into everyday instruction. Visual tools should not be treated as mere supplements but as essential elements of adaptive, innovative, and inclusive education.

Conclusion

Based on the findings and discussion of this study, it can be concluded that the use of visual media in mathematics instruction significantly enhances students' conceptual understanding of solid geometry. The increase in average scores by 10.79 points from the pretest to the posttest provides empirical evidence that this approach effectively improves students' ability to identify geometric elements, interpret nets, and distinguish between three-dimensional figures logically and accurately. Visual media—comprising physical models, 3D illustrations, and animated videos—has been proven not only to clarify abstract concepts by making them more concrete but also to increase students' engagement in the learning process. Students who were previously passive became more active, confident, and capable of expressing their mathematical ideas. This indicates growth not only in cognitive aspects but also in affective and social domains.

Pedagogically, visual-based learning encourages teachers to create a more interactive, inclusive, and student-centered classroom environment. This approach aligns with the *Merdeka Curriculum* and the *Profil Pelajar Pancasila*, which emphasize independent learning, collaboration, and critical thinking. Moreover, visual media supports flexible learning strategies, making it suitable for both remedial and differentiated instruction, accommodating diverse learning needs and styles. The implications of this study highlight the urgent need for teacher training in the design and implementation of effective and contextually relevant visual media. Schools must also ensure the availability of learning resources and technological infrastructure to fully realize the benefits of visual-based instruction. Finally, this research opens new pathways for future studies in other mathematics topics such as symmetry, volume, or geometric transformations, across both elementary and secondary education settings.

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Conflict of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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