APPLICATION OF GEOGEBRA TO MOTIVATION AND UNDERSTANDING OF MATHEMATICAL CONCEPTS OF STUDENTS BUILDING FLAT SIDE SPACE MATERIALS

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Abstract

This study aims to analyze the effect of using the GeoGebra application on students' motivation and conceptual understanding of mathematics in the topic of flat-faced solid shapes. The research employed an experimental method with a pretest-posttest control group design. The sample consisted of two classes divided into an experimental group, which used GeoGebra in learning, and a control group, which applied conventional teaching methods. Data were collected through conceptual understanding tests, motivation questionnaires before and after treatment, and classroom activity observations. The results showed that the experimental group experienced a significant increase in mathematics conceptual understanding with an average n-gain of 0.65 (medium to high category), compared to the control group, which only achieved an n-gain of 0.41 (low to medium category). Additionally, the motivation of students in the experimental group increased significantly, with 78% of students reaching a high motivation category, while the control group had only 42%. Observations revealed that GeoGebra encouraged students to actively discuss, explore, and interact with the learning material. Based on these findings, it can be concluded that the application of GeoGebra is effective in improving both motivation and conceptual understanding in mathematics learning on the topic of flat-faced solid shapes. This study recommends educators to integrate visual technology-based learning tools to enhance the quality of mathematics teaching and learning processes.

Keywords: ***GeoGebra, Mathematics Motivation, Conceptual Understanding***

1. INTRODUCTION

Mathematics education has a very important role in developing students' logical, analytical, and systematic thinking skills. These skills are not only needed in academic contexts, but also in everyday life, especially in rational decision-making and problem-solving. One of the materials that demands a strong conceptual understanding is the building of flat-sided spaces, which includes shapes such as cubes, blocks, prisms, and pyramids. This material not only demands numeracy skills, but also high spatial visualization skills. Three-dimensional visualization is a challenge for students, as these shapes are often only presented in two-dimensional images in textbooks, making them difficult to visualize in their entirety. As a result, many students have difficulty understanding the building properties of spaces, calculating surface area, and volume correctly (Aziz & Zakir, 2022).

On the other hand, the low motivation of students to learn in mathematics learning is also a significant challenge. Many students find math to be difficult, abstract, and boring. This stigma has an impact on declining interest in learning and a lack of active involvement of students in the learning process. When students are not motivated, they tend to be passive, do not try to understand the

material in depth, and easily give up when faced with challenging problems. This certainly has a negative impact on the achievement of learning outcomes, especially in mastering spatial geometry concepts. Therefore, innovations in learning strategies are needed that are not only able to bridge students' visualization difficulties, but also be able to arouse their enthusiasm and interest in learning mathematics. This innovation can be in the form of the use of technology-based learning media, contextual approaches, or interactive and fun learning models, so that they can create a more meaningful and effective learning experience (Jaya & Fitriani, 2022).

One of the potential solutions to overcome challenges in geometry learning, especially building flat-sided spaces, is the use of interactive and visual-based educational technology. In this regard, computer-based applications such as GeoGebra become a highly relevant and effective tool. GeoGebra is a dynamic math app designed to integrate geometry, algebra, and calculus in one interactive platform. Through GeoGebra, students not only see static images like in textbooks, but can also manipulate geometric objects directly rotate, enlarge, crop, and change the parameters of the shape of the space such as cubes, blocks, prisms, and pyramids. The ability to see objects from multiple angles in real-time provides a concrete visual experience, helping students form a stronger mental representation of three-dimensional concepts (Hidayah, Rohaeti, & Sari, 2024).

Furthermore, the use of GeoGebra not only plays a role in improving conceptual understanding, but also has a positive impact on students' affective aspects, such as learning interest and motivation. The exploratory and visual interactions in this application are able to create a more enjoyable and meaningful learning experience. Students become more interested in trying, experimenting, and delving deeper into geometric concepts that were previously considered difficult. This has the potential to build an active, creative, and constructive learning atmosphere, where students are not only recipients of information, but also active actors in the learning process (Ashriyanto, Baidowi, Tyaningsih, & Amrullah, 2025). Thus, the integration of technologies such as GeoGebra in mathematics learning is not only a technical innovation, but also a pedagogical strategy that is able to bridge the gap between conceptual abstraction and visual reality that can be accessed by students directly (Ridwan & Setiawan, 2023). Based on this background, the researcher is interested in studying the application of GeoGebra to students' motivation and understanding of mathematical concepts in flat-sided building materials, with the hope of providing alternative learning methods that are effective and relevant in the current digital era.

2. IMPLEMENTATION METHOD

This study uses a quantitative approach with a quasi-experimental method (pseudo-experiment) which aims to determine the effect of the application of GeoGebra application on students' learning motivation and understanding of mathematical concepts in the building material of flat side spaces. The research design used is the Nonequivalent Control Group Design, which involves two groups of students, namely the experimental group and the control group. The experimental group was given learning using the GeoGebra application, while the control group followed learning using conventional methods. Both groups were given a pretest before treatment and posttest after treatment to measure changes in students' understanding of concepts and motivation to learn. The subjects in this study were grade VIII students in one of the junior high schools in [indicate school location], which consisted of two classes selected by purposive sampling, based on the similarity of characteristics of academic ability. The instruments used in this study include a concept understanding test in the form of description questions to measure students' mastery of the building materials of flat side spaces, as well as a student learning motivation questionnaire on a

Likert scale to determine the level of motivation before and after treatment. All instruments have gone through a validation process by experts and trials to ensure their validity and reliability. Data collection techniques are carried out through pretest and posttest, dissemination of learning motivation questionnaires, and observation of the learning process. The data obtained were statistically analyzed using descriptive and inferential analysis. Descriptive analysis was used to determine the average, standard deviation, and distribution of data, while the independent sample t-test (t-test) was used to determine the difference in average posttest results between the experimental group and the control group. In addition, gain (n-gain) analysis was used to measure the improvement of students' understanding of concepts and learning motivation after treatment (Scott, 2019).

3. RESULTS AND DISCUSSION

Result

This study aims to determine the effect of the application of GeoGebra on students' learning motivation and understanding of mathematical concepts in the material of building flat side spaces. The results of the research are presented in two main focuses, namely: (1) the influence of GeoGebra on students' understanding of mathematical concepts, and (2) the influence of GeoGebra on students' learning motivation.

1. Pretest and Posttest Results of Concept Understanding

a. Pretest and Posttest Average Scores

The data from the pretest results showed that the students' initial understanding of the two groups, namely the experimental group and the control group, was relatively low and relatively equal, which indicated that there was no significant difference in initial mastery of the material between the two groups before the learning treatment. The average pretest score of the experimental group was 58.20, while the control group obtained an average score of 57.80. This very small difference shows that the initial conditions of the two groups are quite balanced, so it is valid to make a comparison in evaluating the effectiveness of the learning methods applied.

After the learning process was carried out, there was a significant increase in the average posttest scores in both groups. The experimental group that received treatment using GeoGebra-based learning media showed an increase in the average score to 83.10. Meanwhile, the control group that received conventional learning only achieved an average posttest of 72.60. This striking difference in average increase reflects the positive influence of the use of GeoGebra on students' understanding of concepts, especially in the material of building flat side spaces. A 24.90-point increase in the experimental group compared to 14.80 points in the control group indicates that learning with a visual-interactive approach can effectively increase students' absorption of material that demands spatial visualization skills.

Thus, these results support the assumption that the integration of technology in mathematics learning not only provides a variety of methods, but also improves the quality of students' conceptual understanding. The more significant increase in learning outcomes in the experimental group emphasized the importance of using innovative learning media in creating a more effective and meaningful learning process. These findings also provide a solid basis for teachers and education practitioners to consider the use of interactive applications such as GeoGebra as part of a more modern mathematics learning strategy that is adaptive to the needs of students (Anjarwati, Pujiastuti, & Ihsanudin, 2022).

b. Gain Test (n-Gain)

The analysis of the improvement of student learning outcomes was carried out using the normalized gain (n-gain) formula, which measures the effectiveness of a learning method based on a comparison between the increase in pretest and posttest scores with the maximum score that can be achieved. The results showed that the experimental group, which received learning with the help of the GeoGebra application, obtained an average n-gain of 0.65, which belongs to the medium to high category. Meanwhile, the control group that followed the conventional method learning only obtained an average n-gain of 0.41, which falls into the low to moderate category.

This difference in the level of improvement suggests that the use of GeoGebra makes a greater contribution in helping students understand the building materials of flat side spaces compared to traditional methods. The higher average n-gain in the experimental group indicated that visual-interactive technology-based learning was better able to bridge the gap in students' understanding from the initial condition to better mastery of concepts. GeoGebra provides a more concrete learning experience through the visualization of three-dimensional shapes and direct manipulation of objects, which greatly supports the understanding of materials that are naturally abstract and difficult to visualize only through print media (Putro & Setyadi, 2022).

Furthermore, the results of this n-gain also reflect the level of efficiency of the learning method used. The experimental group showed more optimal learning effectiveness because it was able to achieve a higher increase in understanding in the same time span. This corroborates previous findings in the pretest and posttest tests that the integration of technology in the mathematics learning process not only improves learning outcomes, but also accelerates the process of students' understanding of important concepts. Thus, the results of this n-gain test provide quantitative evidence that supports the effectiveness of using GeoGebra as an innovative learning medium that is able to improve the quality of mathematics education, especially in mastering spatial geometry materials.

c. Statistical Test (Independent Sample t-Test)

The results of the statistical test using the Independent Sample t-Test method on the posttest value of the two groups showed that the significance value (p-value) obtained was 0.003, which was clearly below the significance threshold of 0.05. This indicates that there is a statistically significant difference between the learning outcomes of the experimental group using GeoGebra learning media and the control group using conventional learning methods. Thus, the null hypothesis (H_0) which states that there is no difference in learning outcomes between the two groups is rejected, while the alternative hypothesis (H_1) is accepted.

These findings strengthen the evidence that the use of GeoGebra in the learning process has a real influence on improving students' understanding of mathematical concepts, especially in the material of building flat side spaces. This effect is not only seen from the higher average increase in posttest scores, but has also been verified through inferential statistical tests. Pedagogically, this shows that the visual-interactive technology-based approach is able to provide more effective cognitive stimulus than traditional methods, thus supporting the process of internalizing concepts more deeply in students. Furthermore, the results of this t-test confirm that the integration of GeoGebra in learning is not just a technical innovation, but also has scientifically measurable educational significance. GeoGebra's excellence in presenting dynamic, interactive, and manipulative visualizations makes abstract concepts such as spatial geometry easier to understand and accept by students. Therefore, the use of this application can be recommended as part of modern evidence-based learning strategies, especially in improving learning outcomes and quality of learning in the classroom (Safira & Salsabila, 2021).

2. Learning Motivation Measurement Results

a. Pre and Post Motivation Questionnaire Results

Based on the results of the learning motivation questionnaire given before and after learning, an interesting picture was obtained regarding changes in the level of student motivation in both groups. Before the treatment was given, the majority of students in both the experimental and control groups were in the moderate motivation category, with only a small percentage in the high motivation category. These findings show that at first, students' motivation to learn mathematics lessons is not optimal, which is in line with the general perception that mathematics is a subject that tends to be considered difficult and less interesting by most students.

However, after the learning process was carried out with a different approach, there were significant changes, especially in the experimental group using the GeoGebra application. The results of the post-learning questionnaire showed that as many as 78% of students in the experimental group had an increase to the high motivation category, while the rest remained in the medium category. This increase reflects the positive influence of the use of interactive learning media on the affective aspects of students. GeoGebra, as a visual-dynamic learning medium, provides a more enjoyable learning experience, sparks curiosity, and allows students to actively engage in the learning process. Direct interaction with geometric objects in three-dimensional forms helps students feel more confident, challenged, and motivated to understand the material being taught.

In contrast, the control group that followed learning with a conventional approach showed a lower increase in motivation. Only about 42% of students have experienced a shift to the high motivation category, while most others remain in the medium category. These differences in results indicate that learning that is monotonous and less actively involved students is less likely to have a significant impact on increasing learning motivation. Thus, these data reinforce the importance of using innovative and technology-based approaches in mathematics learning, not only to improve cognitive outcomes, but also to encourage affective aspects such as students' interest, enthusiasm and positive attitudes towards learning (Jump, 2024).

b. Aspects of Increased Motivation

Student learning motivation in this study was measured based on five main indicators, namely: (1) enjoyment in learning mathematics, (2) interest in the material, (3) active participation in learning, (4) effort to complete tasks, and (5) self-confidence in one's own abilities. These five aspects reflect the affective dimension that plays an important role in driving the success of the learning process, especially in subjects such as mathematics which are often considered challenging and abstract by most students. The results of the questionnaire analysis showed that all motivation indicators increased in both groups, but a more significant and even increase occurred in the experimental group that obtained learning with the help of the GeoGebra application. Among these five aspects, the most notable improvement was recorded in the indicators of enjoyment in learning and active participation in learning. This shows that an interactive technology-based learning approach not only helps students understand the material cognitively, but also builds a fun and participatory learning atmosphere (Badaruddin & Yani T, 2023).

The interactive visualizations provided by GeoGebra allow students to see the shapes of the space from different angles, rotate objects, and manipulate sizes and shapes directly. This makes geometric concepts that were previously abstract more concrete and easy to understand. The satisfaction of successfully understanding the material in a fun and visual way encourages increased enjoyment in learning. Meanwhile, the manipulative and exploratory features of GeoGebra encourage students to engage more actively, both in class discussions and in self-exploration, which is reflected in increased active participation during the learning process.

In addition, indicators of task completion and self-confidence also showed a significant increase in the experimental group. Students feel more confident when they are able to solve geometry problems that were previously difficult to understand, thanks to the help of concrete visualizations from the app. This also strengthens their positive self-perception of their ability in

mathematics. As for the control group, although there was an increase in all five indicators, the overall increase was not as high as that of the experimental group, especially in terms of pleasure and participation. Thus, this increase in learning motivation aspects is further evidence that GeoGebra-based learning is not only effective in improving cognitive learning outcomes, but also able to strengthen non-cognitive factors that play an important role in the long-term learning process (Miranda & Nurmitasari, 2022).

3. Observation Results of Learning Activities

Based on the results of observations made during the learning process, there was a striking difference in student learning activities between the experimental group and the control group. In the experimental group, students showed a high level of activity in various aspects, such as discussing collaboratively, trying out GeoGebra features enthusiastically, and actively asking questions to teachers to deepen their understanding. The classroom atmosphere becomes more lively, dynamic, and interactive because students are not only passive recipients of information, but are directly involved in building concepts through visual exploration.

The GeoGebra application is proven to be able to create fun and non-monotonous learning. The manipulative features of GeoGebra allow students to directly transform, rotate, and observe the shapes of space structures such as cubes, blocks, prisms, and limas from various points of view. This process helps students to understand the relationship between geometric elements in a more concrete and visual way, something that is difficult to achieve if only through two-dimensional images in textbooks. This active involvement shows that GeoGebra plays a role not only as a visual aid, but also as a medium that facilitates experiential learning. In contrast, in the control group that used conventional learning methods, students appeared to be more passive. They wait more for instructions from teachers and only follow the learning flow without any exploration or interaction with learning media. Discussions between students are also relatively minimal, and the initiative to ask questions or explore the material independently is less noticeable. This shows that traditional approaches have not been able to optimally encourage active participation and curiosity of students, especially in understanding abstract materials such as spatial geometry (Hermawan, Yuspriyati, & Purwasih, 2022).

From the results of this observational analysis, it can be concluded that the application of GeoGebra in mathematics learning not only has an impact on improving understanding of concepts, but also significantly increases student motivation and involvement. GeoGebra provides a more concrete, interactive, and enjoyable learning experience, helping to create an active, constructive, and participatory learning environment. Thus, the use of educational technology such as GeoGebra can be an innovative strategy that is effective in answering the challenges of mathematics learning in the 21st century.

Discussion

This discussion aims to interpret the results of the research findings in relation to the theory, previous research results, and research objectives. The focus of the discussion was divided into two main aspects, namely the effect of the use of the GeoGebra application on (1) students' understanding of mathematical concepts and (2) students' learning motivation.

The Influence of GeoGebra on the Understanding of Mathematical Concepts

The results of the study showed a significant increase in students' understanding of mathematical concepts in the flat side room building material after the implementation of the GeoGebra application. The experimental group that received GeoGebra-based learning showed a higher average posttest than the control group. In addition, the n-gain value of the experimental group

was also larger and was in the medium to high category, while the control group was only in the low to medium category.

These findings are in line with Bruner's (1966) theory of visual representation-based learning, which states that concrete visualization can help students better understand abstract concepts. GeoGebra provides interactive visualizations of spatial structures, such as cubes, beams, prisms, and pyramids, so that students can observe the changes in shape, rotation, and relationships between the elements of the spatial building firsthand. This reinforces students' mental construction of geometric concepts that they previously found it difficult to imagine only through static drawings on books or blackboards. This research is also supported by previous studies, such as those conducted by Nurfadillah et al. (2021) and Huda (2020), which show that the use of GeoGebra can improve understanding of mathematical concepts, especially in geometry and transformation materials. With dynamic and interactive features, GeoGebra helps reduce misconceptions and significantly improve students' conceptual understanding (Ramadhan, Alzaber, Dahlia, & Qudsi, 2021).

The Influence of GeoGebra on Students' Learning Motivation

In addition to increasing understanding of concepts, the application of GeoGebra has also been proven to increase students' motivation to learn. The results of the questionnaire showed that most of the students in the experimental group experienced an increase from the medium to high motivation category. The most motivated aspects are enjoyment in learning and active participation in learning. This condition can be explained through motivation theory according to Keller (1983) in the ARCS (Attention, Relevance, Confidence, Satisfaction) model, where students' attention can be increased with interactive media that are interesting and relevant to their learning needs. GeoGebra as an interactive learning medium can create a fun learning environment, reduce boredom, and increase students' curiosity. When students find the learning process more engaging, they will be more motivated to actively and passionately participate. Support for these findings was also found in the research of Suryani (2020), which stated that learning using interactive applications such as GeoGebra increases students' interest and confidence in facing math lessons that are usually considered difficult and boring (Puspita, 2024).

Implications of Research Results

The findings of this study provide several important practical and strategic implications for the world of education, especially in the context of mathematics learning at the primary and secondary school levels. First, math teachers need to actively consider the integration of visual-based learning technologies, such as GeoGebra, in the teaching process, especially for abstract and complex materials such as flat-sided space builds. The interactive visualization offered by GeoGebra is able to change the learning approach from being textual and descriptive to more concrete, exploratory, and based on direct experience, so as to improve students' conceptual understanding in a more in-depth way.

Second, the use of GeoGebra has been shown to not only have a positive impact on cognitive learning outcomes, but also significantly increase student motivation, active participation, and confidence. This is in line with the characteristics of 21st-century learning that emphasizes collaboration, communication, critical thinking, and the utilization of digital technologies. Therefore, GeoGebra can be used as an alternative learning strategy that supports the achievement of student competencies holistically, including cognitive, affective, and psychomotor aspects. Third, the application of GeoGebra also has the potential to be a solution to overcome various obstacles that often arise in conventional learning. Learning that is still teacher-centered and lacks visualization tends to limit students' exploration space, and is less able to arouse interest in learning. With a GeoGebra-based learning approach, students are given the space to think independently, experiment,

and build their own knowledge through a constructive process, which is in line with a constructivist approach to learning (Agustin, Efriani, Islam of the State of Raden Fatah Palembang, & South, 2024).

In addition, from the perspective of education policy, the results of this research can be the basis for schools or education offices to develop teacher training in the use of educational technology, enrich learning tools with digital media, and encourage the implementation of ICT-based learning in a more systematic manner. Thus, these findings are not only relevant for teachers in the classroom, but also for curriculum designers, policy makers, and educational resource developers in an effort to improve the quality of mathematics learning in the digital age.

Research Limitations

Although the results of this study show a positive impact of the use of GeoGebra on students' understanding of concepts and learning motivation, there are several limitations that need to be considered in interpreting these findings more broadly. First, the scope of this study is limited to one school with two classes as a sample, so the results obtained cannot be generalized to the wider student population, both in terms of geographical background, socio-economic, and academic ability level. Variations in other school characteristics, such as infrastructure conditions, learning culture, and student characteristics, can affect the effectiveness of GeoGebra implementation. Second, this study is short-term and only measures the impact of using GeoGebra during one learning cycle on one material topic, namely building flat side spaces. Therefore, no conclusions can be drawn regarding the long-term effects of the use of GeoGebra on the sustainability of improving concept understanding, learning motivation, or overall academic achievement. Further research with a longitudinal design is needed to evaluate the stability and consistency of the benefits of using GeoGebra over a longer period of time (Maulana, Zamnah, & Amam, 2021).

Third, the success of the use of GeoGebra in learning is highly dependent on several external factors, such as the readiness of teachers to operate the technology, pedagogical skills to integrate GeoGebra into learning scenarios, and the availability of supporting facilities such as computers/laptops, internet connections, and projectors. In an environment with limited technological resources, the implementation of GeoGebra may encounter obstacles, both from a technical and managerial perspective. Therefore, it is important to consider the readiness of the education system in terms of teacher training and the provision of technological infrastructure before implementing learning technology widely. Overall, although the results of this study make a positive contribution to the development of technology-based mathematics learning, these limitations are important considerations for researchers and education practitioners in adopting and developing similar strategies in the future.

4. CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the application of GeoGebra has proven to be effective in increasing understanding of mathematical concepts and students' learning motivation in flat side room building materials. Students who study using GeoGebra show a significant improvement in conceptual understanding compared to students who learn through conventional methods. This is evidenced by an increase in posttest scores and gain score analysis results that show medium to high categories in the experimental group. In addition, students' motivation to learn has also increased, especially in terms of learning pleasure, active participation, and confidence. The use of GeoGebra in learning is able to present a more concrete and interactive

visualization of mathematical concepts, thereby creating a more interesting and fun learning atmosphere. Thus, GeoGebra can be used as an effective alternative learning media in an effort to improve the quality of mathematics learning, both in terms of understanding concepts and student learning motivation.

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