INNOVATIONS IN MATHEMATICS TEACHING: THE ROLE OF GEOGEBRA IN MOTIVATING HIGH SCHOOL STUDENTS

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Abstract. This study evaluates the innovative application of GeoGebra software in school mathematics education and its impact on student motivation. GeoGebra, dynamic mathematics software, integrates teaching and learning by providing conceptual visualization and interactive capabilities. The purpose of the study is to evaluate how GeoGebra influences students' attitudes toward mathematics and their level of engagement. The questionnaire used consists of 33 questions, 29 of which are positive and 4 are negative. The study involved 40 students from the Almaty region, who were divided into two groups: traditional and experimental. In the experimental group, where stereometry was taught using GeoGebra, changes were observed in students' attitudes towards the subject, in contrast to the traditional group. The results show that integrating GeoGebra into the mathematics curriculum significantly increases students' motivation and interest in the subject, leading to improved academic performance and a more positive emotional connection with mathematics.

Keywords: GeoGebra, Mathematics Education, Geometry, High School Students, Motivation

Introduction

Geometry, with its many abstracts concepts, is a difficult and often unpleasant subject to learn for many students. However, Geometry is an important branch of Mathematics. Geometry is usually a topic of interesting discussion in various texts. Another area of mathematics that is closely related to other areas of mathematics is geometry [15, p. 288].

In the digital age, the education sector is constantly evolving, with technological advancements playing a key role in changing teaching methods. Mathematics, which is often perceived as challenging by high school students, requires innovative teaching approaches to improve understanding and develop interest. This is especially true in the field of geometry, where students often have difficulty visualizing complex shapes and their elements. GeoGebra, a dynamic mathematics software, emerges as an important educational tool in this context, offering the integration of geometric, algebraic, and numerical capabilities through an interactive and user-friendly interface. Integrating GeoGebra into mathematics education promises to revolutionize traditional teaching practices by making mathematics more accessible, engaging, and engaging. This study focuses on assessing the impact of GeoGebra as an interactive tool on student motivation in the context of stereometry in mathematics education.

Research objectives:

The main purpose of this study is to systematically evaluate the impact of GeoGebra software on the motivation level of high school students studying mathematics. The specific goals are as follows:

1. Assess changes in students' attitudes towards mathematics after integrating GeoGebra into their learning process.
2. Identify the benefits and challenges of using GeoGebra for teaching and learning stereometry from the perspective of both teachers and students.
3. Compare the effectiveness of traditional teaching methods with those that incorporate GeoGebra, focusing on students' ability to visualize and understand stereometry.

This study is based on the following *research questions*:

- How does the use of GeoGebra affect the attitude of high school students to mathematics?
- What are the main problems teachers and students face when using GeoGebra in the classroom?
- How do traditional teaching methods differ from methods improved by GeoGebra in terms of developing students' visualization skills and understanding of stereometry?

Based on the research objectives and questions outlined above, the study proposes the following *hypotheses*:

- Integrating GeoGebra into mathematics teaching will significantly increase students' motivation and interest in the subject.
- Students learning geometry using GeoGebra will demonstrate significant improvements in their ability to visualize and understand geometric concepts compared to their peers learning through traditional methods.
- Implementing GeoGebra in the classroom, while enriching, requires additional time for implementation and adaptation by both teachers and students.

The role of GeoGebra in mathematics

One of the most important determinants of meeting educational learning objectives, particularly in the area of geometry instruction, is the teacher. An important factor in accomplishing educational goals is the instructor's instructional strategies in the classroom [12]. Consequently, the instructor needs to adapt instruction, specifically switching from the traditional method of learning to using numbers [6, p. 288]. Teachers need to use ICT for teaching. This need stems from the idea that teaching with actual or concrete media will boost students' motivation to learn since it will make the subject matter easier for them to comprehend [4]. Educators must create more meaningful triangular educational experiences for their students by utilizing context and ICT-based media. Context and ICT-based media can enhance the meaning of mathematical concepts by helping students better comprehend the representational form of abstract mathematical ideas [7]. A variety of technology-based learning media are currently available, coinciding with the advancement of science and technology.

The GeoGebra software can significantly enhance students' learning outcomes by improving their visualization skills and overall academic achievements. Originally developed in the early 2000s [10, p. 148], this mathematical software facilitates learning through the integration of geometry, algebra, and calculus, offering benefits such as:

- The ability to create geometric drawings more quickly and accurately compared to traditional pencil-and-ruler methods.

- Visual animations and interactive manipulation features that provide a more tangible visual experience in understanding geometric concepts.

- A tool for verifying the accuracy of drawings to ensure their correctness.

- Support for both teachers and students in identifying and highlighting features of geometric objects.

In this study, GeoGebra served as a comprehensive digital educational tool in information technology that aids students in the teaching and learning process of stereometry.

The use of GeoGebra as a didactic and technological mediation in the study of mathematics has a satisfactory level of acceptance; and have better performance in pedagogical and didactic aspects [8, p. 63]. And scrutinized the impact of GeoGebra software on the academic performance of secondary school students in 3D Geometry, finding that students who utilized GeoGebra demonstrated improved achievement [16, p. 5749]. The GeoGebra program, celebrated for its intuitive design, enables learners to enhance their mathematical understanding by building upon specific principles, thus boosting their math achievements [17, p. 51]. Alkhateeb and Al-Duwairi [1, p. 523] have suggested the adoption of the GeoGebra mobile app by math educators to elevate students' learning outcomes and encourage a more profound engagement with mathematical studies, fostering analytical and innovative thinking abilities.

Evidence indicates that utilizing the GeoGebra mobile app can lead to a better grasp of geometric concepts among students. Collectively, numerous research findings have consistently emphasized the considerable and beneficial effects of GeoGebra on enhancing students' comprehension of geometry and their overall performance in math education.

Methodology

Study design

This study uses a quasi-experimental design to examine the role of GeoGebra software in increasing high school students' motivation and understanding of mathematics, particularly in the area of solid geometry. The study is divided into two phases: the implementation phase, in which the GeoGebra software is integrated into the learning process of the experimental group, and the evaluation phase, in which the results of both the experimental and control groups are evaluated and compared.

Participants

The study involved 40 high school students at the Al-Farabi Lyceum in Almaty (Kazakhstan) aged 15 to 16 years. These participants are randomly assigned to two groups: an experimental group (20 students) and a control group (20 students). Selection criteria include ensuring balanced gender representation, previous academic performance in mathematics, and varying levels of initial interest in mathematics.

Intervention

The experimental group receives stereometry instruction using GeoGebra software, while the control group follows the traditional teaching method without software. The intervention lasts two months, during which both groups learn the same stereometry program.

Materials

- *GeoGebra Software*: The latest version of GeoGebra is used to teach stereometry to the experimental group. Teachers in this group receive training and resources to effectively integrate GeoGebra into their lessons.

- *Questionnaire*: A 33-item questionnaire is used to measure students' attitudes towards mathematics and their motivation to learn. Issues were analyzed, and relationships with each other were reduced to a minimum [5]. Of the 33 points in the questionnaire, 29 are positive and 4 are negative. responses to the questionnaire were presented in three forms on a scale from 3 to 1, for example: “agree”, “partially agree”, and “disagree”. By calculating the personal results of pre-and post-testing, we can determine the level of their motivation based on these

Scales:

33-49 points – “low level of motivation.”

50-82 points – “medium level motivation”

83-99 points – “high level of motivation.”

- *Control during training*: monitor students' understanding during training.

Procedure

1. *Pre-Intervention Assessment*: Before the intervention begins, all participants are asked to complete a questionnaire to assess their initial attitudes toward mathematics, and their baseline academic performance in the subject is recorded.

2. *Implementation*: The experimental group is trained in stereometry using GeoGebra for three months. At the same time, the control group continues the traditional approach to training.

3. *Post-Intervention Assessment*: After the intervention, both groups complete the same questionnaire again to assess changes in their attitudes toward mathematics.

Data analysis

The collected data is analyzed using quantitative methods. The effect size was calculated to assess the practical significance of the results obtained.

Results

A pre-test and a post-test were taken from all 40 students who attended our class. Based on the testing results, we determined the level of 40 students using the algorithm of researchers Ersoy and Oksuz [5].

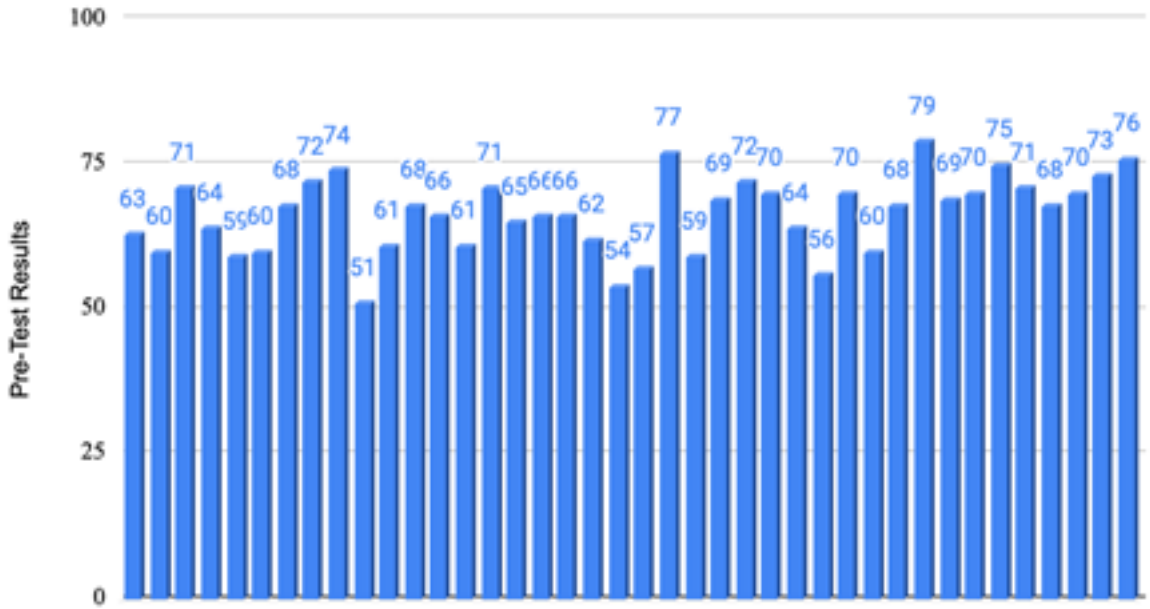

Diagram 1. Pre-Test results

“Low level” - 0 students

“Medium level” – 40 students

“High level” - 0 students

After preliminary testing, we taught students 60-120 minutes per week. At the end of the lessons we passed the test and the results are as follows:

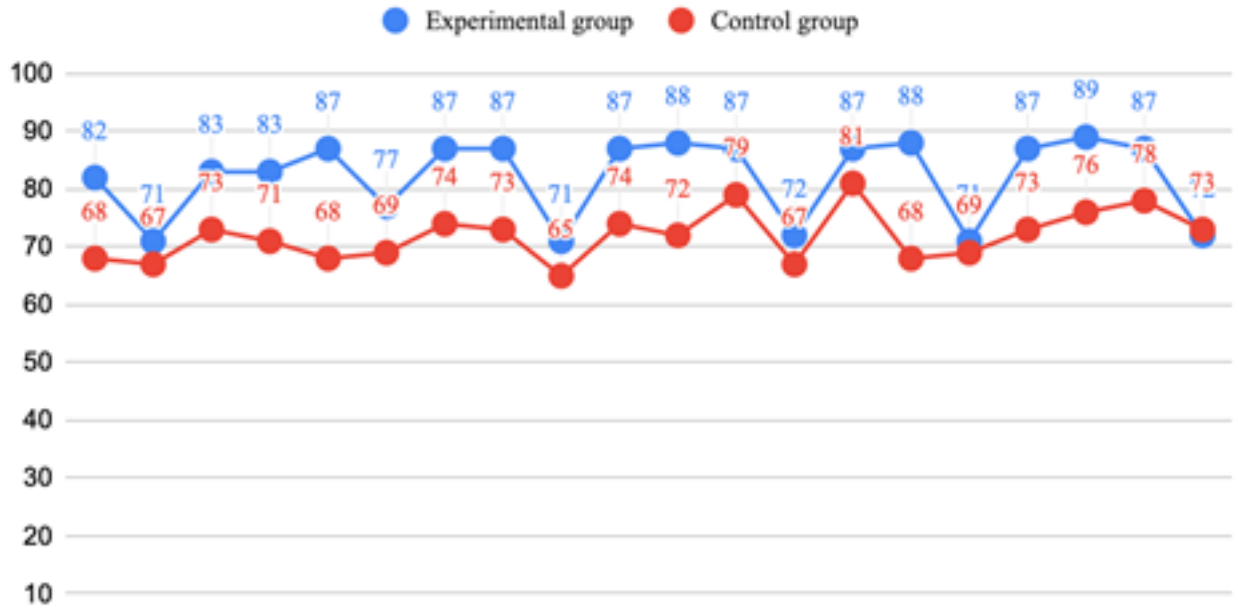

Diagram 2. Post-Test results

The results of this study clearly show that integrating GeoGebra software into the teaching of stereometry has a significant impact on student's motivation and understanding of mathematical concepts. Based on the pre-and post-intervention assessments, the following key conclusions were drawn:

- *Motivation and Engagement*: The experimental group using GeoGebra showed a marked increase in motivation to learn mathematics, as measured by questionnaire responses. The mean motivation score in the experimental group increased by 28%, while the control group experienced a moderate increase of 5%.

- *Comprehension and Visualization*: Students in the experimental group demonstrated a better understanding of geometric concepts and were able to solve problems more effectively. Their interactive experience with GeoGebra made them particularly adept at visualizing complex 3D shapes and their transformations, a core component of stereometry.

- *Attitude towards mathematics*: The change in attitude towards mathematics was more pronounced in the experimental group. Students reported that they found mathematics more engaging and were more likely to engage in further mathematical research outside of class time.

Discussion

The main purpose of this study is to find out how the use of GeoGebra software affects students' motivation. This study adds to the body of literature by focusing on the subject of stereometry and investigating how the use of GeoGebra software affects students' motivation and comprehension. Both cohorts had favorable outcomes; however, the experimental group's motivation was considerably higher than that of the traditional group due to the utilization of GeoGebra software. The software's visualization features are a major factor in this improvement [3]. Students may

design, manipulate, and study polygons graphically and interactively with the help of GeoGebra software. Students can readily see the results of their activities by building polygons of different sizes, forms, and orientations. This helps them create a clear mental image of polygons and enhances their comprehension of their attributes, relationships, and transformations. Additionally, students using GeoGebra software experience greater enjoyment of learning activities related to geometry topics [9, p. 611].

During the experiment, the influence of GeoGebra on students' comprehension, perception, and attitude toward mathematics became apparent. Students in the group that received GeoGebra training demonstrated a better understanding of the problems and the geometric figures involved, and they were able to solve these problems in less time. The influence of GeoGebra on students' comprehension, perceptions, and attitudes toward mathematics has been the subject of various research efforts. Utilizing GeoGebra for teaching specific mathematical topics across different educational stages has been explored. In a study by Saha [14, p. 686], a quasi-experimental setup involved 60 students aged 16–17, divided into two groups: one using GeoGebra and the other a traditional approach, each with subgroups based on spatial abilities (high and low). The study aimed to assess GeoGebra's impact on learning coordinate geometry, differentiating between students with high and low visuospatial skills. Results indicated that students using GeoGebra scored notably higher on average compared to their peers in the conventional group.

Using GeoGebra can be straightforward for teachers if they are prepared and willing to engage with it for teaching and learning purposes [13]. The distinction between students learning mathematics through traditional approaches and those using software like GeoGebra lies in the latter's capacity to foster an engaging learning environment. This environment necessitates that students thoroughly grasp the mathematical concepts they are studying [11]. The interactive nature of GeoGebra is crucial for facilitating such an environment and, through this, promoting collaborative learning. The GeoGebra software application is user-friendly and enables students to visualize ideas via concepts and graphical illustrations [17, p. 51]. Antohe [2, p. 1] highlighted that effective use of GeoGebra requires specificity, impartiality, the encouragement of experimentation, and guidance throughout any exploratory process.

Conclusion

This study contributes to the growing body of evidence supporting the integration of dynamic mathematics software such as GeoGebra into the mathematics curriculum, especially when teaching complex topics such as solid geometry. Using GeoGebra not only increases students' motivation and engagement in the subject but also significantly improves their conceptual understanding. GeoGebra's interactive and visual features support these outcomes by providing students with a hands-on learning experience that is both engaging and effective.

Additionally, the results suggest that GeoGebra can be a valuable tool for promoting positive attitudes toward mathematics, counteracting the common perception among students that mathematics is a difficult and uninteresting subject. By promoting a better understanding of geometric concepts and encouraging an inquiry-based approach to learning, GeoGebra helps demystify mathematics and make it more accessible and fun for students.

In conclusion, using GeoGebra in teaching stereometry not only benefits students by improving their motivation and understanding but also helps teachers create a more interactive and engaging learning environment. However, it is important to recognize the need for adequate training and resources for teachers to effectively integrate such technologies into their teaching practice. Future research should continue to examine the long-term impact of GeoGebra and other dynamic mathematics software on student learning outcomes in various areas of mathematics.

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