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Visualization of Teaching Space Geometry Using GeoGebra in Upper Secondary Schools: A Review of Literature

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Abstract

This research investigated the potential of GeoGebra software as a visual aid in teaching space geometry within upper secondary schools. The study evaluated the effectiveness of GeoGebra by comparing the quality of instruction and student learning outcomes achieved with and without its implementation. Furthermore, it explored teachers' perspectives on utilizing GeoGebra to teach geometric concepts. The methodology involved a comprehensive review of existing literature on the application of GeoGebra in secondary school space geometry instruction. The researcher gathered and analyzed 38 relevant research papers to synthesize current understanding of the topic. The analysis of the selected papers suggests that GeoGebra software is a valuable asset in secondary mathematics education. The findings highlight GeoGebra's ability to enhance students' comprehension of three-dimensional concepts through visual representation, ultimately improving their learning experience.

Keywords: Visualization, GeoGebra, Teaching Space Geometry, Secondary School

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Introduction

The current study was motivated by the need to enhance students' comprehension of complex geometric concepts through dynamic and interactive learning tools. While numerous studies have explored the use of GeoGebra in mathematics education, limited literature specifically addresses its effectiveness in teaching space geometry at the upper secondary level. Existing research highlighted the benefits of visualization in improving students' three-dimensional reasoning, yet gaps remain regarding

the extent to which GeoGebra facilitates conceptual understanding, engagement, and problem-solving skills in three-dimensional geometry. This review aimed to synthesize existing studies, identify trends, and bridge the knowledge gap by analyzing how GeoGebra can be effectively integrated into space geometry instruction.

About 20% of Malaysian students fail to achieve the minimum benchmarks in mathematics. A GeoGebra workshop was conducted with 30 secondary school teachers, and the findings indicate that teachers have positive perceptions of the use of technology in teaching mathematics. It should be used as an alternative to replace traditional methods for teaching mathematics (Zakaria en Lee, 2012). Besides this, students from a high school in Riau, Indonesia, took part in the study; the study's findings highlight differences in students' conceptual and procedural knowledge based on their ability and student groups; the findings have ramifications that support the use of GeoGebra to improve students' mathematics knowledge (Hutkemri, 2014). A study was conducted on 62 Malaysian students to determine the effectiveness of utilizing GeoGebra software on mathematics achievement. The experimental group was taught how to use the GeoGebra software to answer geometry tasks, but the control group did not have access to GeoGebra, the findings showed that students have some positive attitudes toward studying and attain higher levels of learning achievement when using GeoGebra (Arbain en Shukor, 2015).

The rapid development of educational technology has led to the introduction of various educational software tools to enhance learning (Singh, 2018). One such tool, GeoGebra, has been widely studied for its effectiveness in teaching space geometry. For instance, a study conducted at Malaysian Tidar University found that GeoGebra-based learning significantly improved the problem-solving abilities of second-semester mathematics education students, whereas the control group showed no such improvement (Pamungkas & Nugroho, 2020). Similarly, research conducted in Turkey at Ankara University and the Turkish National University for Higher Education highlighted that while GeoGebra helps students contextualize abstract mathematical concepts, those with low computer literacy face challenges in effectively utilizing the software (Celen, 2020). These findings align with a study in Kenya, which demonstrated GeoGebra's effectiveness in enhancing secondary school students' geometry performance and emphasized the need for proper teacher training to maximize its impact. Furthermore, the study developed a GeoGebra guidebook prototype for Kenyan mathematics teachers, recommending its integration into secondary school geometry instruction as a means to bridge the gender gap in mathematics learning (Mukiri, 2016). These studies collectively highlight the global relevance of GeoGebra in space geometry education while underscoring the importance of teacher preparedness and digital literacy in ensuring its successful implementation.

The effectiveness of GeoGebra in teaching and learning Geometric Transformations (GT) at the 'O' level secondary schools in Zimbabwe was evaluated using a mixed-methods approach that included semi-structured interviews with mathematics teachers and written pre and post-tests for both groups of learners; traditional methods improved traditional students' performance, As a result; GeoGebra improved its performance in ICT even more (Mukamba en Makamure, 2020). South African National Development Plan (NDP) calls for the use of high-quality technology in the classroom to improve learning outcomes. In South African high schools, GeoGebra is one of the most popular mathematics programs; the key finding was that ICT equipment was being stolen and vandalized from high schools (Mokotjo en Mokhele, 2021). Moreover, understanding, analytical thinking, abstract thinking, representation, and logical reasoning were all improved with geometry, the majority of the papers that were evaluated

looked into the use of GeoGebra in geometry; other mathematical fields, such as algebra, calculus, and trigonometry, had few investigations (Uwurukundo, Maniraho en Tusiime, 2020).

Rwanda has made significant progress in integrating ICT into teaching and learning, with various initiatives aimed at enhancing digital education (Fajebe et al., 2013; Maurice, 2021; Munyengabe et al., 2017). For instance, some secondary teachers received computers and projectors in public schools under the One Laptop per Teacher program. However, challenges such as insufficient computer laboratories, poor internet connectivity, and a shortage of trained ICT teachers continue to hinder the effective use of technology in education (Fajebe et al., 2013; Maurice, 2021; Munyengabe et al., 2017; Rubagiza et al., 2011; Uwanyirigira, 2017).

Despite efforts to integrate ICT, secondary mathematics teachers in Rwanda still struggle with misconceptions about certain mathematical concepts (Mugiraneza, 2021; Munyengabe et al., 2017; Sylvestre et al., 2018). These misconceptions can negatively impact students' understanding, particularly in complex topics such as space geometry, where conceptual clarity is essential for effective learning. Addressing these misconceptions requires innovative instructional strategies, including the use of dynamic visualization tools like GeoGebra.

One of the major challenges in learning geometry is its abstract nature, which makes it difficult for students to grasp spatial relationships and three-dimensional concepts (Widada et al., 2021). Students may struggle to comprehend and apply geometric principles without proper visualization. This challenge highlights the need for technology-enhanced teaching methods that facilitate conceptual understanding (Ndihokubwayo, 2024) through interactive and visual representations.

The use of GeoGebra in teaching space geometry has been shown to enhance students' ability to visualize three-dimensional concepts, making learning more intuitive and engaging (Aktumen et al., 2011; Septian et al., 2020). GeoGebra helps bridge the gap between abstract mathematical theories and their practical applications by providing dynamic visual representations. This improves students' comprehension and fosters a deeper interest in geometry.

In addition to benefiting students, GeoGebra also enhances teachers' experience with space geometry. Studies indicate that teachers who incorporate GeoGebra into their instruction find the subject more enjoyable and accessible, improving their ability to teach complex concepts effectively (Berger, 2013; Celen, 2020; Furner & Marinas, 2012). The software encourages teachers to visualize, explore, and engage with geometric content in ways that traditional teaching methods may not facilitate, ultimately leading to improved instructional practices.

In today's world, information and communication technologies have an impact on the field of education, which is on teaching, learning, and research (Yusuf, 2005). Teachers must utilize effective teaching techniques to gain necessary information about specific civilizations. Students were expected to get a complete understanding of their academic courses and to appreciate how to build innovative knowledge by using information and communication technologies as tools (UNESCO, 2015). The use of ICT tools has stimulated the interest of the education community to improve meaningful mathematics teaching and learning. However, it also engages students in instructional activities to increase their learning and assist them in solving complex mathematical problems to improve their cognitive skills (Michael P. Clough Joanne K. Olson, 2013). Three-dimensional presented in a two-dimensional classroom environment on the blackboard leads to less visualization of the concept of space geometry in teaching (Kaufmann en

Schmalstieg, 2002; Emmanuel en Pacifique, 2007; Azizul en Din, 2016; Jelatu, Sariyasa en Made Ardana, 2018). The use of a dynamic geometric environment is suggested in order to visualize these ideas of 3-D geometry (Valko, 2022).

Related Literature

The use of GeoGebra is a tool for teaching and learning space geometry

To begin with, the study conducted on the topic "Integrating GeoGebra into Space Geometry in College". The study aimed to examine the impact of using GeoGebra on the mathematics achievement of pre-service mathematics teachers in space geometry learning. A total of 56 students were selected from the mathematics education program of Tidar University, a state university located in Magelang, Central Java, Indonesia. The experimental group (27) was taught about the slice plane in the prism and pyramid using GeoGebra, while the control group (29) was taught about using traditional teaching methods. Findings show that GeoGebra was an effective tool for teaching and learning space geometry in College (Pamungkas, Rahmawati en Dinara, 2020). A conducted study on the topic "Synthesis of Modeling, Visualization, and Programming in GeoGebra as an Effective Approach for Teaching and Learning STEM Topics." The study aimed to discuss how GeoGebra provides an environment for learning that is very interactive and collaborative between the learner and the instructor. The study's results are that GeoGebra is integrated into the current curriculum, and teaching approaches have proven highly effective in various studies in different mathematical and STEM-oriented fields (Ziatdinov en Valles, 2022).

The effectiveness of using GeoGebra in teaching and learning space geometry in secondary school

The study on the topic "The effects of using GeoGebra teaching strategy in Malaysian secondary schools: A case study from Sibu, Sarawak". The study aimed to examine the effects of using GeoGebra Teaching Strategy in Learning Circle III topic on Malaysian Secondary Form Four students' performance and attitudes towards this teaching strategy. A quasi-experiment of non-equivalent pre-posttest control group design study was conducted in a school in Sibu, Sarawak. One control group (n=17) and one experimental group (n=29) were randomly selected from Form Four classes. The Circle III Achievement Test and the Attitude Questionnaire were used as instruments in this study. The data were analyzed using one way ANOCA and one sample t-test. The experimental students showed positive attitudes toward using GeoGebra software while learning Circle III topic (Masri *et al.*, 2016).

A conducted study on the topic "Innovative strategies on teaching plane geometry using GeoGebra software in secondary schools in Delta state". The purpose of the study was to examine the effectiveness of GeoGebra software strategies and teaching of plane geometry in secondary schools in Oshimili-South Local Government Area of Delta State. The Instrument for this study was a Performance Mathematics Ability Test (PMAT). The findings showed that there was a significant difference between the mean performances of students' when taught plane geometry using GeoGebra software and problem-based learning but no significant difference with respect to gender (Onaifoh en Ekwueme, 2017).

For more, a conducted study on the topic "The Effect of GeoGebra in Three-Dimensional Geometry Learning on Students' Mathematical Communication Ability". The purpose of the study was to analyze the effect of GeoGebra in three-dimensional geometry learning on students' mathematical communication ability as a whole and based on students' prior mathematical abilities. This quasi-

experimental research with randomized post-test only design included 84 XIII grade students in high school in Central Jakarta, Indonesia. Findings showed that students' mathematical communication ability in three-dimensional geometry given by GeoGebra were higher than students taught with conventional learning (Kusumah, 2020).

The teachers' perception to use of the GeoGebra for teaching and learning space geometry in secondary school

A conducted study on the topic "Implementation of Space Geometry Learning Using GeoGebra to Improve Problem Solving Skills". The purpose of this research was to get an overview of improving prospective mathematics teachers' problem-solving skills by implementing GeoGebra on space geometry learning. The results showed that (a) GeoGebra-based Space Geometry learning can improve problem-solving skills, and (b) In the experimental group, problem-solving skills were improved in the high category while in the control group, the improvement of problem-solving skills in the moderate category (Pamungkas en Nugroho, 2020).

In the same year, a conducted study on the topic "Students Opinions on the Use of GeoGebra Software in Mathematics Teaching." The purpose of the study was to determine the teachers' views of 7^{th}-grade students about the usage of GeoGebra on lines and angles. The case study approach and focus group interview method were used in the study. The results of the research showed that (a) GeoGebra makes mathematics learning processes fun and enjoyable, (b) it helps students in concretizing abstract concepts often found in mathematics, and (c) students with low computer literacy have hardship in applying GeoGebra activities (Celen, 2020).

A study was conducted on the topic "Analysis of GeoGebra Activities and Opinions of Primary Mathematics Teacher Candidates." The study aimed to examine the activities of primary mathematics teacher candidates with the help of GeoGebra, dynamic geometry software, and their perspectives on GeoGebra software. A semi-structured open-ended question form was used as a data collection tool. It has been determined that teacher candidates who have the opportunity to think about the causality of rules and formulas have positive opinions such as interest, motivation increase, and desire to use again (Korkmaz, 2021).

In the same year, a study was conducted on the topic "Improving the learning environment for future mathematics teachers with the application of the dynamic mathematics system GeoGebra AR." The research aims to transform the traditional educational environment for training future mathematics teachers using the GeoGebra AR dynamic mathematics system and the introduction of cloud technologies into the educational process. Effectiveness and practical tools for teaching mathematics based on GeoGebra AR using interactive models and videos for mixed and distance learning of students are provided; the examples showed that the use of the GeoGebra system allows making the teaching of mathematics practice-oriented, applying research methods, and increasing the motivation of students' learning (Osypova en Tatochenko, 2021).

Furthermore, a study on the topic "Teachers' status of GeoGebra Use in the Teaching of Geometric Transformation." This study investigated teachers' perspectives toward using GeoGebra as a tool to enhance the learning of Geometric Transformation. The study participants included 98 secondary mathematics teachers in a district of Northern Malaysia. A mixed-methods approach with closed-ended and open-ended questionnaires was employed in this study. Data analysis was performed descriptively

and via thematic content analysis. The finding reveals that only 15.3% of teachers use GeoGebra in their mathematics classroom, even though teachers believe that their students struggle with geometry. GeoGebra has been recommended by the Malaysian Mathematics Curriculum and is provided in textbooks (Musa, Mamat en Ghazali, 2021).

Methods

To investigate the current study, the researcher conducted a comprehensive literature review. The study aimed to gather relevant insights on how GeoGebra facilitates the teaching and learning of space geometry through visualization techniques. A systematic approach was adopted to identify and analyze scholarly works that discuss the role of GeoGebra in enhancing students' 3-D reasoning and conceptual understanding of three-dimensional geometry.

A collection of relevant research articles was retrieved from the Google Scholar database to support the study. The search process involved using carefully selected keywords, including visualization, GeoGebra, and teaching space geometry in secondary school. These keywords were chosen to ensure that the literature captured studies directly related to the integration of GeoGebra in teaching space geometry, its effectiveness, and challenges associated with its implementation in upper secondary education.

From the 56 studies initially identified, a total of 38 papers were carefully reviewed and included in the study based on their relevance to the research topic. The selection process focused on studies that provided empirical evidence, theoretical discussions, and practical applications of GeoGebra in teaching space geometry. These selected articles offered valuable insights into how GeoGebra enhances students' visualization skills, improves engagement, and supports teachers in delivering complex geometric concepts effectively.

Results and discussions

Table 1. Two studies on the use of GeoGebra as a tool for teaching and learning space geometry are examined in the literature.

Authors	Title	Purpose	Instruments	Findings
Pamungkas et al. (2020)	Integrating GeoGebra into Space Geometry in College.	To examine the impact of using 'GeoGebra' on the mathematics achievement of pre-service mathematics teacher students in space geometry learning.	Questionnaire	The results showed that GeoGebra was an effective tool for teaching and learning space geometry in college.
Ziatdinov & Valles (2022)	Synthesis of Modeling, Visualization, and Programming in GeoGebra as an Effective	To discuss how GeoGebra provides an environment for learning that is very interactive and collaborative	-	Integrating GeoGebra into the current curriculum and teaching approaches has proven highly effective in various

	Approach for Teaching and Learning STEM Topics.	between the learner and the instructor.	studies in different mathematical and STEM-oriented field.

The findings from the reviewed literature indicated that GeoGebra plays a significant role in enhancing the teaching and learning of space geometry, particularly by improving students' understanding of three-dimensional concepts. The study by Pamungkas et al. (2020) demonstrated that GeoGebra serves as an effective tool in college-level mathematics education, supporting pre-service mathematics teachers in developing their spatial reasoning skills. This suggests that integrating GeoGebra into secondary education could provide similar benefits by equipping students with interactive tools to visualize and manipulate geometric objects.

Moreover, Ziatdinov and Valles (2022) highlighted that GeoGebra raises an interactive and collaborative learning environment. Their findings emphasize that GeoGebra is a visualization tool and an instrument that enhances engagement between learners and instructors. This aspect is particularly important in secondary education, where fostering student participation is essential for effective learning. If properly integrated into the curriculum, GeoGebra could help address common learning difficulties in space geometry by allowing students to dynamically explore and experiment with geometric transformations.

A key insight from these studies is the importance of embedding GeoGebra into existing teaching methodologies. While Pamungkas et al. (2020) focused on the effectiveness of GeoGebra in improving mathematical achievement, Ziatdinov and Valles (2022) expanded the discussion by emphasizing its application across various STEM disciplines. This suggests that space geometry instruction should incorporate GeoGebra and align it with broader interdisciplinary learning goals. Students can develop a deeper appreciation for geometry's relevance in science, engineering, and technology.

Additionally, the reviewed studies underline the need for structured implementation strategies to maximize the benefits of GeoGebra. Although both studies support the effectiveness of GeoGebra, neither provides detailed guidelines on how to integrate the tool into secondary school classrooms systematically. This raises concerns about potential challenges, such as inadequate teacher training, lack of access to digital resources, and varying levels of student digital literacy. Future research should explore ways to ensure that teachers receive the necessary support to integrate GeoGebra effectively.

Another key observation is the potential of GeoGebra to enhance problem-solving skills in space geometry. Pamungkas et al. (2020) suggested that pre-service teachers who used GeoGebra performed better in spatial reasoning tasks compared to those who did not. This aligns with prior research emphasizing the role of dynamic geometry software in improving students' ability to analyze and construct three-dimensional objects. If this finding extended to secondary school students, it could strongly justify promoting GeoGebra as a standard tool for teaching space geometry.

Despite its advantages, the effectiveness of GeoGebra depends on teacher preparedness and student familiarity with technology. While Ziatdinov and Valles (2022) approve GeoGebra's interactive features, they do not address the digital divide that may hinder its adoption in certain educational settings. In low-resource environments, schools may struggle to provide the necessary infrastructure, such as computers and reliable internet access, to support GeoGebra-based instruction. Therefore, policymakers and

teachers need to develop strategies to make GeoGebra accessible to a wider range of students.

Moreover, the studies suggested that GeoGebra can bridge the gap between abstract and practical learning. Space geometry is often perceived as a challenging topic due to its abstract nature, but GeoGebra allows students to manipulate geometric figures dynamically, making concepts more tangible. This aligns with broader pedagogical theories advocating for active learning strategies, where students engage directly with mathematical concepts rather than relying solely on static textbook representations. Therefore, the reviewed literature strongly supports the integration of GeoGebra into space geometry instruction. However, successful implementation requires proper teacher training, resource availability, and alignment with curricular goals. Future research should focus on developing structured guidelines for GeoGebra integration, addressing technological barriers, and exploring its long-term impact on students' mathematical performance.

Table 2. Three studies on the effectiveness of using GeoGebra in teaching and learning space geometry are examined in the literature

Authors	Title	Purpose	Instruments	Findings
Masri et al. (2016)	The effects of using GeoGebra teaching strategy in Malaysian secondary schools: A case study from Sibu, Sarawak.	To examine the effects of using the GeoGebra Teaching Strategy in learning Circle III topic on Malaysian Secondary Form Four students' performance and attitudes towards this teaching strategy.	Questionnaires were used.	The experimental students showed positive attitudes towards using GeoGebra software while learning the Circle III topic.
Onaifoh and Ekwueme (2017)	Innovative strategies on teaching plane geometry using Geogebra software in secondary schools in Delta state.	To examine the effectiveness of Geogebra software strategies and teaching of plane geometry in secondary schools in Oshimili-South Local Government Area of Delta State	The Instrument for the study was a Performance Mathematics Ability Test (PMAT).	The findings showed that there was a significant difference between the mean performances of students' when taught plane geometry using GeoGebra software and problem-based learning but no significant difference with respect to gender.
Kusumah (2020)	The Effect of GeoGebra in Three-Dimensional Geometry Learning on Students'	To analyze the effect of GeoGebra in three-dimensional geometry learning on students 'mathematical	Randomized Control Group Post Test Only Researcher.	Students' mathematical communication ability in three-dimensional geometry who given

	Mathematical Communication Ability Yaya.	communication ability as a whole and based on students' prior mathematical abilities.	by GeoGebra were higher than students taught with conventional learning.

The findings from the reviewed studies provide strong evidence supporting the effectiveness of GeoGebra as a teaching tool in enhancing students' understanding and engagement in geometry. Masri et al. (2016) examined the impact of GeoGebra on Malaysian secondary students learning the Circle III topic and found that students exhibited positive attitudes toward this teaching strategy. The study suggested that GeoGebra's dynamic and interactive nature raises engagement and motivation among learners. The implication of this finding was that integrating technology such as GeoGebra into mathematics instruction may significantly improve students' learning experiences and perceptions of the subject matter.

Similarly, Onaifoh and Ekwueme (2017) investigated the effectiveness of GeoGebra in teaching plane geometry in Delta State, Nigeria. The study revealed a significant difference in students' performance when taught using GeoGebra compared to problem-based learning. This indicates that GeoGebra positively impacts students' comprehension and problem-solving skills in plane geometry. However, the study found no significant gender-based difference, suggesting that GeoGebra's effectiveness is independent of students' gender. This finding is particularly relevant for educators and policymakers aiming to implement gender-inclusive teaching strategies.

Kusumah (2020) further explored the effect of GeoGebra on students' mathematical communication abilities in three-dimensional geometry. The study employed a randomized control group design and found that students who were taught using GeoGebra exhibited higher mathematical communication abilities than those taught through conventional methods. This finding highlighted the role of technology in raising conceptual understanding and communication skills in mathematics. Given that mathematical communication is essential for problem-solving and critical thinking, integrating GeoGebra into instruction may enhance students' ability to articulate and apply mathematical concepts effectively.

A common trend observed across these studies was the effectiveness of GeoGebra in enhancing students' performance and engagement. The software's interactive and visual approach appears to make abstract geometric concepts more tangible and comprehensible. This aligns with constructivist learning theories, which emphasize the importance of active engagement and visualization in learning mathematical concepts. Furthermore, the positive student attitudes reported by Masri et al. (2016) suggest that GeoGebra improves academic performance and fosters a more positive perception of mathematics, which is crucial in addressing mathematics anxiety among students.

Despite the evident benefits, the studies reviewed did not explore long-term retention of knowledge gained through GeoGebra-based instruction. While students showed improved performance and communication skills immediately after intervention, future research should investigate whether these benefits persist over time. Additionally, factors such as teachers' proficiency in using GeoGebra and the availability of necessary resources may influence the effectiveness of its implementation in different educational settings.

Another area for further investigation is the integration of GeoGebra with other pedagogical

approaches. While Onaifoh and Ekwueme (2017) compared GeoGebra with problem-based learning, future studies could explore its combination with cooperative learning or inquiry-based instruction to determine the most effective teaching strategies. Moreover, understanding students' cognitive processes while using GeoGebra could provide deeper insights into how the software enhances mathematical reasoning and problem-solving skills.

The findings suggest that GeoGebra is a valuable tool in geometry instruction, offering significant advantages over conventional teaching methods. Its ability to enhance engagement, improve performance, and support mathematical communication underscores its potential in modern mathematics education. However, more research is needed to examine its long-term impact, effectiveness across diverse student populations, and optimal integration with other teaching strategies. Addressing these gaps will provide a more comprehensive understanding of how GeoGebra can be effectively utilized to improve mathematics education globally.

Therefore, the reviewed literature supports the integration of GeoGebra in secondary school mathematics instruction, particularly in geometry. The consistent findings across different geographical contexts indicate its broad applicability and potential for enhancing student learning outcomes. However, educators must consider contextual challenges such as teacher training and resource availability to ensure its successful implementation. Future research should focus on longitudinal studies and comparative analyses with other technological tools to further establish its effectiveness and sustainability in mathematics education.

Table 3. Five studies on the teachers' perception of the use of the GeoGebra for teaching and learning space geometry are examined in the literature

Authors	Title	Purpose	Instruments	Findings
Pamungkas and Nugroho (2020)	Implementation of Space Geometry Learning Using Geogebra To Improve Problem-Solving Skills.	To get an overview of improving the problem-solving skills of prospective mathematics teachers by implementing GeoGebra on space geometry learning.	Tests	The results showed that GeoGebra-based Space Geometry learning can improve problem-solving skills.
Celen (2020)	Student Opinions on the Use of Geogebra Software in Mathematics Teaching.	To determine the teachers' views of 7th grade students about the use of geogebra on lines and angles.	The case study approach and focus group interview.	It was concluded that Geogebra makes mathematics learning processes fun and enjoyable, helps students in concretizing abstract concepts often found in mathematics, and that students with low computer literacy have

				difficulty applying Geogebra activities.
Korkmaz (2021)	Analysis of Geogebra Activities and Opinions of Primary Mathematics Teacher Candidates.	To examine the activities of primary mathematics teacher candidates with the help of Geogebra, dynamic geometry software, and their perspectives on Geogebra software.	Semi-structured open-ended question form was used.	It has been determined that teacher candidates who have the opportunity to think about the causality of rules and formulas have positive opinions such as interest, motivation increase, and desire to use them again.
Osypova and Tatochenko (2021)	Improving the learning environment for future mathematics teachers by applying the dynamic mathematics system GeoGebra.	To transform the traditional educational environment for training future mathematics teachers with the use of the GeoGebra dynamic mathematics system, the introduction of cloud technologies into the educational process.	Effective and practical tools for teaching mathematics based on GeoGebra using interactive models and videos for mixed.	The examples show that the use of the GeoGebra system allows making the teaching of mathematics practice-oriented, apply research methods, and increase the motivation of students' learning.
Musa et al. (2021)	Teachers' Status of GeoGebra Use in The Teaching of Geometric Transformation.	To investigate teachers' perspectives towards the eventual use of GeoGebra as a tool to enhance the learning of Geometric Transformation.	Questionnaires	Findings showed that only 15.3% of teachers use GeoGebra in their mathematics classroom, even though teachers are of the view that their students have difficulties in learning geometry.

The reviewed literature highlighted the effectiveness of GeoGebra in mathematics education, particularly in improving problem-solving skills, making abstract concepts more accessible, and increasing student engagement. Across different studies, a common theme emerges: the integration of dynamic geometry

software like GeoGebra enhances learning experiences, yet challenges persist in its adoption, especially concerning teachers' readiness and students' digital literacy.

Pamungkas and Nugroho (2020) examined the impact of GeoGebra-based instruction on space geometry learning. Their findings indicate that the software significantly improves problem-solving skills among prospective mathematics teachers. This aligns with constructivist learning theories, which emphasize active engagement with mathematical concepts through visualization and interaction. The results suggest that GeoGebra can serve as a powerful pedagogical tool for enhancing higher-order thinking skills, particularly in spatial reasoning and geometric problem-solving.

Similarly, Celen (2020) investigated the perceptions of 7th-grade students regarding GeoGebra's application in learning lines and angles. The study found that students perceive GeoGebra as a tool that makes mathematics learning enjoyable and aids in visualizing abstract concepts. However, it also highlighted a challenge: students with low computer literacy struggled to effectively engage with GeoGebra activities. This underscores the need for proper digital literacy training before implementing technology-driven mathematics instruction.

Korkmaz (2021) extended this inquiry by analyzing the experiences of primary mathematics teacher candidates using GeoGebra. The study found that these candidates developed a deeper understanding of mathematical causality, leading to increased interest and motivation. This finding suggested that integrating dynamic software in teacher training programs can raise more effective pedagogical practices by enabling future educators to intuitively understand mathematical principles.

The role of GeoGebra in transforming traditional educational environments was further explored by Osypova and Tatochenko (2021). Their study demonstrated that the integration of GeoGebra and cloud technologies into teacher training programs creates a practice-oriented learning environment. The findings indicate that interactive models and videos facilitated through GeoGebra enhance students' research skills and motivation. This study supports the idea that digital tools can be leveraged for knowledge dissemination and fostering a more inquiry-based approach to mathematics education.

Despite these positive outcomes, challenges persist in the widespread adoption of GeoGebra, as highlighted by Musa et al. (2021). Their investigation into teachers' perspectives on using GeoGebra for teaching geometric transformations revealed that only 15.3% of teachers actively incorporate the software into their instruction. This is a striking contrast to the otherwise positive findings regarding GeoGebra's effectiveness. The study suggests that barriers such as lack of training, limited resources, and resistance to technological integration may delay its adoption in classroom settings.

A critical takeaway from these studies is that while GeoGebra offers substantial benefits in mathematics education, its implementation is contingent on multiple factors, including teacher preparedness, student digital literacy, and institutional support. The success of technology-enhanced learning environments depends not only on the availability of digital tools but also on the ability of educators and learners to utilize them effectively.

Moreover, these findings emphasize the importance of structured professional development programs for teachers to build competence in GeoGebra usage. Even the most innovative digital tools may fail to achieve their intended learning outcomes without adequate training. Therefore, education policymakers and curriculum designers should prioritize teacher capacity-building initiatives to facilitate the seamless integration of GeoGebra into mathematics instruction.

Additionally, equity in access to technology remains a concern. While studies highlight the effectiveness of GeoGebra, they also reveal disparities in students' ability to engage with the software due to varying levels of digital literacy. Addressing this issue requires a more inclusive approach, ensuring that all students receive foundational digital training to bridge the gap between traditional and technology-driven learning environments.

Another noteworthy observation is that GeoGebra raises an inquiry-based learning approach, allowing

students to explore mathematical concepts through experimentation. The ability to visualize and manipulate geometric structures can lead to a deeper conceptual understanding compared to traditional static teaching methods. Future research could explore longitudinal studies to assess whether sustained use of GeoGebra leads to long-term improvements in mathematical reasoning and problem-solving abilities.
Therefore, the reviewed literature highlighted GeoGebra's potential to enhance mathematics education by improving problem-solving skills, increasing motivation, and making abstract concepts more accessible. However, successful implementation necessitates addressing challenges related to teacher training, digital literacy, and equitable access to technology. Future studies should explore strategies to overcome these barriers and further investigate the long-term impact of GeoGebra on students' mathematical development.

Conclusion and Recommendation

In three-dimensional geometry, GeoGebra students demonstrated higher mathematical communication abilities. The previous research suggested that using GeoGebra software while studying can improve mathematical abilities and increase student interest. The findings also showed that students who learned using GeoGebra had better spatial ability than students who learned using other instructional methods. Geogebra exercises were challenging for students with fewer computer skills. Students may concretely understand abstract ideas typically encountered in mathematics with the help of GeoGebra. Further study found that teachers employed GeoGebra in mathematics classrooms even when they thought their students had problems comprehending geometry. According to the recommendations, more mathematics software, particularly GeoGebra, should be made available in classrooms.

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