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Integrating *GeoGebra* in Teaching Hyperbolic Geometry: Experiences and Insights of Math Majors in the New Normal

Raymond C. Negros, Roel Victor O. Morales, Cresselyn Joy C. Villabeto, Dezerie B. Mendoza, Jepie N. Reyes, Michael Jun M. Ponciano
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Abstract

To maintain high educational standards, technological advancements are integrated into classroom discussions, with GeoGebra being a prominent tool in mathematical teaching. This study explores how GeoGebra is utilized to teach hyperbolic geometry in an online learning environment. The research involved eight third-year students and one teacher participating in semi-structured interviews with open-ended questions. Using a descriptive study approach and thematic analysis, the study identified challenges faced by students in proving theorems and properties in hyperbolic geometry, primarily due to unfamiliarity with GeoGebra's features and the availability of necessary devices and resources. To address these issues, the researchers proposed an intervention model that includes providing a computer lab with GeoGebra installed, ensuring stable internet access, and restructuring lesson plans to effectively integrate GeoGebra into teaching. The researchers also recommended implementing these interventions in related course instruction to assess their effectiveness and contribution to enhancing the learning experience.

Keywords: *interventions, lesson plan, mathematics education, online learning, technology*

Introduction

The integration of dynamic mathematics software, which combines mathematical concepts into an interactive and user-friendly interface, has significantly transformed the landscape of mathematics education. Technology-enhanced learning environments have had a profoundly positive impact on both teaching and learning in mathematics (Lischka, Sosnovsky, & Heinze, 2019). Research by Karsli (2018) and Muhtadi, Kartasasmita, and Prahmana (2017) supports the notion that technology positively influences achievement and attitudes in mathematics. Among the various software tools used in teaching mathematics, GeoGebra stands out as a widely utilized option. This online software is dynamic, incorporating geometry, algebra, spreadsheets, graphing, statistics, and calculus. It is available as a free software package that can be used both online and offline, providing tools for creating mathematical constructions, exploring mathematical ideas, and solving problems.

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Many studies have examined and described GeoGebra as an effective tool for teaching geometry-related courses. These studies assert that GeoGebra is both effective and advantageous (Pamungkas, Rahmawati, & Dinara, 2020; Jelatu & Andara, 2018; Tamam & Dasari, 2021) in improving mathematics teaching and learning. This implies that the use of GeoGebra in all math-related classes, especially in geometry, offers significant benefits for both teachers and students in achieving required competencies.

Furthermore, the application helps students visualize problems, aiding them in determining which theorems or formulas need to be applied, as well as in proving particular theorems, such as those in hyperbolic space. This paper describes the integration of GeoGebra in teaching hyperbolic geometry in an online context. Additionally, it addresses the challenges of integrating this mobile application into teaching hyperbolic geometry based on students' experiences. The findings significantly contribute to formulating possible interventions through an intervention model for teachers and academia, enhancing technology-integrated discussions, specifically with GeoGebra.

Literature Review

GeoGebra as Instructional Material in Mathematics and Related Disciplines

Technology paves the way for providing a conducive and effective environment for teaching and learning algorithms. It has produced both advanced and traditional techniques that aid teachers in improving their pedagogical approaches. Supporting this, Ain et al. (2019) described how technological tools increase interaction between teachers and students in the teaching and learning process. In mathematics, various software and applications have been developed to ease students' difficulties in learning the subject.

GeoGebra is one of the applications that function on mobile phones, laptops, and other devices, aiding in the learning of geometry-related subjects and courses. Developed in 2002 by Markus Hohenwarter, GeoGebra was designed to provide visual representations of geometrical objects. It includes several methods, such as the bisection method, the secant method, the false-position method, and the Newton-Raphson method. GeoGebra is also used in calculus courses and beyond. According to Olivares and Valero (2019), GeoGebra was used to facilitate the visualization of a non-homogenous second-order linear differential equation in engineering differential equations courses. This was supported by Asare and Atteh (2022), who showed that students who used GeoGebra in their learning process enhanced their understanding of transformation (rigid motion) concepts.
GeoGebra is a highly effective tool for visualizing geometric concepts, particularly for below-average learners (Mthethwa et al., 2020). It aids in understanding rational inequalities (Jupri, 2021), linear equations and slopes (Birgin & Yazici, 2021), and exponential and logarithmic functions (Birgin & Acar, 2020). Mudaly and Fletcher (2019) found that integrating GeoGebra in teaching linear algebra helped students recognize properties of straight-line graphs. Pamungkas (2019) noted its utility in drawing diagrams for geometry problems. Hussen et al. (2021) observed that GeoGebra simplifies linear programming for industrial engineering students, and Hobri et al. (2019) highlighted its effectiveness in supporting

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linear programming through web-based e-comics.

GeoGebra is a versatile tool not only for modeling and visualizing mathematical concepts but also for constructing proofs. Oli and George (2020) reported that GeoGebra improves performance in trigonometry for students with dyscalculia. Studies agree on its significance in proving theorems. Beyond geometry, GeoGebra is also effective in learning calculus. According to Sari et al. (2018), it aids in exploring derivatives through dynamic visualization, providing insights and solutions to problems. Wassie and Zergaw (2018) found that GeoGebra helps students distinguish tangent lines and points on curves dynamically, creating an effective learning environment. Nielsen and Solov'yov (2019) highlighted its utility in problem-solving, offering various perspectives. Kholid et al. (2020) noted that teachers can use GeoGebra to create sketches, facilitating problem-solving with precise and accurate visual illustrations.
Physics, a branch of science that deals with math-related concepts such as speed, kinetic problems, and quantum physics, can benefit greatly from GeoGebra. Studies have used GeoGebra to address various issues, including dynamic image formation of vector motion components (Flehantov & Ovsiienko, 2019), chemical kinetics and friction (Solvang & Haglund, 2018), and engineering problems involving mathematics and physics (Spyros & Nikolaos, 2013). The app's visual representation aids in the interpretation of graphs, leading to a better understanding of trigonometric functions and graphs (Mosese & Ogbonnaya, 2021). GeoGebra has proven useful in these areas of physics.

GeoGebra as a Tool to Promote Student's Achievement and Interest
GeoGebra is a valuable tool for teaching and learning not only in various branches of mathematics but also in related disciplines such as statistics, physics, and chemistry. It is essential for effective teaching and learning, enhancing mathematical competency relevant to students' performance and real-life contexts.

GeoGebra helps students use algebraic and geometrical functions simultaneously with interactive dynamics, enhancing their cognitive abilities (Zetriuslita, 2020).

Moreover, students become more motivated to study concepts such as rational inequalities (Jupri, 2021), linear equations and slopes (Birgin & Yazici, 2021), and exponential and logarithmic functions (Birgin & Acar, 2020). When students are motivated, their academic results are likely to improve. Additionally, the project-based learning model aided by GeoGebra helps students become more self-reliant in their studies, enhances their problem-solving skills, and maximizes the opportunities provided by technology (Septian & Prabawanto, 2020).

Dahal et al. (2022) note that in the era of Industrial Revolution 4.0, students use many ICT tools for interaction, such as flipped classrooms, mobile apps, and clicker devices. GeoGebra, a pedagogical tool for teaching mathematics (Putra et al., 2021), is valuable for quickly, accurately, and efficiently visualizing abstract geometrical concepts (Tamam & Dasari, 2021). It helps

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relate mathematics to students' everyday experiences by creating graphs, images, and animations. Compared to traditional methods, using dynamic geometry software like GeoGebra improves spatial visualization and problem-solving skills (Baranova & Katrenicova, 2018). In the current context of virtual classrooms, students prefer learning with software, which enhances their technological proficiency and broadens their knowledge.

Integrating GeoGebra is beneficial in both student-centered and teacher-centered approaches. Asare and Atteh (2022) found that GeoGebra enhances students' motivation to learn transformations, making lessons more interesting and encouraging active participation. The software was effective in helping students correctly answer examples, and they expressed a desire for its use in teaching other mathematics topics. Exploring GeoGebra allows teachers to improve their pedagogical knowledge and skills, providing an opportunity for a more engaging and interactive classroom atmosphere (Ziatdinov & Valles, 2022).

Challenges in using GeoGebra Technology is a vital factor in the modern world, especially in mathematics education. Many software applications, such as GeoGebra, ease the teaching and learning process. According to Wassie and Zergaw (2019), GeoGebra is a suitable teaching resource that improves student engagement and achievement in upper secondary and tertiary mathematics. It is particularly useful for visualizing topics in geometry, such as hyperbolic geometry. Despite its success and importance, GeoGebra is not without challenges and problems that individuals may encounter while integrating it.

Mokotjo and Mokhele (2021) identify that challenges related to the introduction of ICT in teaching and learning have been recognized since as early as 1999. These challenges are classified into two categories: first-order and second-order barriers. First-order barriers involve issues with access to and support for using technology, while second-order barriers pertain to teachers' beliefs about how ICT should be used in teaching and learning, including pedagogical beliefs and classroom technology practices.

Moreover, research findings reveal that GeoGebra enables students to make mathematical generalizations and makes the teaching process more engaging and enjoyable (Celen, 2020). However, students with limited computer literacy or those who dislike collaborative environments often struggle with GeoGebra applications. Even among computer-literate students who enjoy collaborative work, these challenges can hinder the effective and efficient use of GeoGebra.

GeoGebra is an effective tool in teaching and learning concepts in Mathematics and beyond related disciplines such as statistics and physics. Moreover, the application can be utilized in improving students' interest in learning mathematics and improving their motivation in learning. It has been proven that the said program is an effective instructional tool in teaching Mathematics due to the many conducted studies and published articles. However, no product of technology is perfect which means it still has disadvantages that come as

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challenges in the perception of its end users. These challenges were part of the experiences and insights of students in learning hyperbolic geometry. Through experiences, students may be able to provide information that is useful in developing teachers' integration of GeoGebra in teaching hyperbolic geometry in an online set-up. On that note, this paper would like to argue the integration of GeoGebra in teaching hyperbolic geometry in a distance learning set-up. Moreover, this paper filled the gap about the challenges in the integration of this certain mobile application in the context of teaching hyperbolic geometry based on the experiences of students in dealing with the aforementioned topic during the distance delivery mode of teaching and learning.

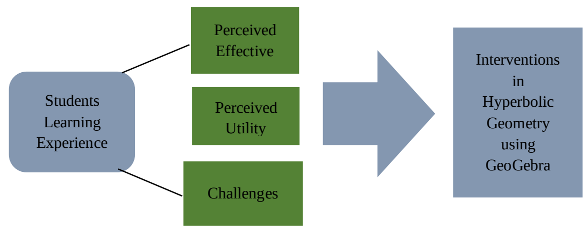
Moreover, it added some information that comes from the side of students and teachers.

Hence, the findings provided vital information in formulating possible interventions to the teachers in contributing to the enhancement of technology-integrated discussions.

Theoretical/Conceptual Framework

Figure 1 shows the conceptual framework of the study. It is anchored on the reality that experiences of key individuals concerning a certain object convey the utility and effectiveness of such an object. In this study, the experience of these students in the use of GeoGebra in learning hyperbolic geometry is a lens to assess the utility and effectiveness of GeoGebra. In addition, as the nature of one's experience is multiply faceted it may convey challenges, or mechanisms to better the utility and effectiveness of GeoGebra in teaching and learning specifically on the concept of hyperbolic geometry.?

Figure 1. Conceptual Framework of the Study



The findings will be the basis of the researchers in providing intervention to aid the teachers in employing the *GeoGebra* application in teaching hyperbolic geometry.

Methodology

The study used a descriptive research design, which focuses on describing phenomena, events, or significant occurrences as they happen. According to Creswell (1994), this method is used to gather information about the current state of affairs. Creswell (2012, p. 274) further explains that the objective of the descriptive technique is to provide a comprehensive and systematic description of the research target (cited in Rusianty, 2015). Thus, a descriptive research approach is suitable for achieving the study's objectives.

The collected data were analyzed using thematic analysis, a qualitative method

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involving the identification of patterns and themes from raw information. Coding and categorizing were applied to these themes, leading to the development of an intervention model. To ensure data reliability and validity, bracketing and triangulation were used, comparing data from students, teachers, and previous studies. Performance levels were described according to the university's manual. The study focused on integrating GeoGebra in teaching hyperbolic geometry in an online context. A descriptive research approach was suitable for this purpose. Initially, three participants were included, but this number increased to eight students and one teacher by the end of data collection. A semi-structured interview guide with open-ended questions was used, and its validity and reliability were confirmed through revisions by experts. The interviewer, trained and experienced in conducting interviews, followed strict ethical considerations in data collection.

The participants of the studies are eight (8) Mathematics Majors enrolled in the 1st Semester of A. Y. 2021 – 2022 taking the course Modern Geometry. Among the eight (8) participants, four (4) of them are male and the remaining four (4) are female. The table below shows the number of respondents in terms of sex.

Table 1. *Demographic profile of the participants in terms of sex*

Category	Number of Participants
Male	4
Female	4
TOTAL	**8**

In terms of gadgets used in accessing *GeoGebra*, commonly used gadget were mobile phones and laptops. This is seen from the responses of the chosen participants in which five of them were solely using mobile phones, (preferably androids), one is using laptop only, and one is choosing both. The table below shows the summary of participants using such gadgets.

Table 2. *Gadgets availability of the participants*

Gadgets	Number of Participants using it
Mobile Phones	7
Laptop	2

Moreover, students' self-assessment of their performance yielded a mean of 5.75. This indicates an average performance level according to the measurement criteria by Aithal, Dillon, and Kumar (2019) in a competency-based education system. This suggests that students are performing at an average level in Modern Geometry.

According to their course professor, the class performance is approximately 6, which is above average using the same criteria. Based on the data from both students and the professor, the researchers conclude that the students' performance level is average and fairly good. The students are proficient in applying the concepts and skills acquired in Modern Geometry, including the use of GeoGebra to prove theorems and properties in hyperbolic geometry.

The study utilized a semi-structured interview guide, which included guide questions. This allowed the researchers to add follow-up questions during the

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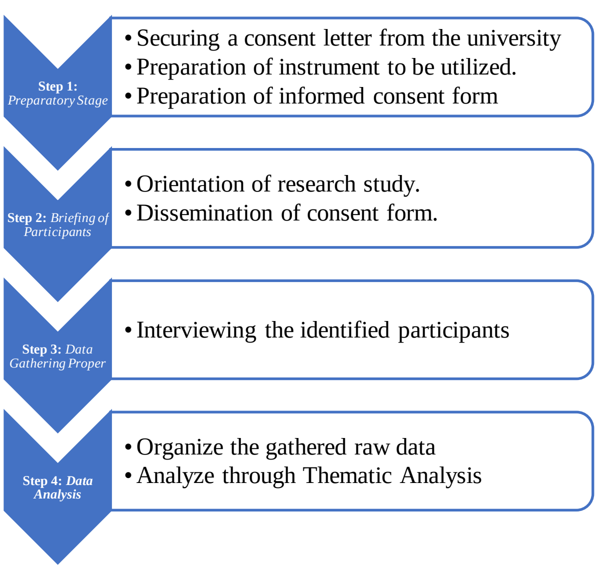
interviews to extract necessary information from the participants. The interview guide collected the following information: (1) name (optional), (2) sex, (3) gadget used, (4) self-rating, and (5) guide questions. Additionally, the researchers ensured that the research instrument would provide the necessary information for the study. The instrument was evaluated for credibility, transferability, dependability, and confirmability (Trochim, 2006). A teacher in the field of Mathematics, a research instructor, and a research adviser were tasked with checking and evaluating these criteria.

To analyze the raw data from the interview, the collected data were tabulated to produce themes for each objective of the proposed study. The data regarding the grade and self-rating will be scored to determine the performance level in class. In addition, the same questions for the students (participants) has been asked to the subject teacher in order to provide triangulation (see data analysis). Figure 2 below shows the data collection procedure.

Figure 2. Data Gathering Procedure



The collected data were analyzed by extracting raw information from the instrument through thematic analysis. Thematic analysis, as defined, is a qualitative analysis method that involves reading through raw information and identifying patterns in meaning-making from data. Coding and categorizing were employed that emerged themes. From these themes, synthesizing was utilized resulting in the creation of an intervention model. The triangulation approach is applied to make sure that the data is reliable and valid. Triangulation happens during the comparison of data gathered from student-participant, teacher, and studies conducted before the study. Further, the level of performance will be described in accordance with the university's manual.

Results and Discussion

On Improvement to Academic Performance

Theme: *GeoGebra as a tool to improve academic achievement and interest*

Despite the difficulty in familiarizing themselves with the features and utility of GeoGebra, students find the application useful as it helps them visualize problems, making them easier to prove and solve. The application provides a clear perspective on the problems, enabling students to comprehensively discuss the properties and theorems needed for proofs. This finding underscores the purpose and advantages of the application. Below are some excerpts from participants supporting this theme:

"It gives me a better illustration and helps me with my proof." – MM3 (Interview Transcript)"… it makes my journey easy in answering problems and my output is

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presentable also." – MM7 (Interview Transcript)"Benefits through virtual representation of abstract concepts." – MM6 (Interview Transcript)

Additionally, teachers have noted students' feelings towards the utility of the application. According to the course teacher, limited resources may cause frustration or sadness among students, as features vary across different gadgets. Nevertheless, students often feel happy or inspired, as the features help them in proving theorems and properties in hyperbolic geometry.

"Some students were happy/inspired that they made constructions using the application, others might be frustrated or sad for not maximizing the learnings on how to use the application due to limited resources." – TM (Interview Transcript) On Utility and Experiences

Theme 1: Difficulty and Familiarity of using GeoGebra

The study reveals that in an online setup, where most students only use mobile applications and lack experience with GeoGebra, it is challenging for them to use the application effectively and efficiently. All participants unanimously agreed that the difficulty in using GeoGebra and its unfamiliar features impacted their experience. The following are some excerpts from the students:

"… it was hard as there are features in it that I am not familiar with… Mastering the features and learning how to use GeoGebra really helped me a lot." – MM1 (Interview Transcript)

"… I find it hard also to this software because I'm not used to it." – MM2 (Interview Transcript)

"Lack of knowledge in utilizing the said platform." – MM6 (Interview Transcript)

The course teacher supported these findings, stating that the use of GeoGebra makes the students' learning journey more interesting. However, the limited features of some gadgets (e.g., mobile phones) and the availability of other gadgets, which depend on the students' resources, affect the utility of the application.

"They find it interesting… However, it was challenging for them to use the application because of the limited use of computers or even unavailability of these." – TM (Interview Transcript)

Theme 2: Challenges encountered in using GeoGebra

Most Math majors agreed that their familiarity with the features and the availability of resources affect their learning experience. Many of them find the software difficult to understand, as the features on mobile phones differ from those utilized on computers.

"… being not familiar with the features of the software or the software itself." – MM1 (Interview Transcript)"…

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lack of knowledge on how to use it." – MM2 (Interview Transcript)

"*... using my mobile phone and the features are limited.*" – MM3 (Interview Transcript) On Intervention towards Effectiveness and Efficiency

Theme: Ways to effectively and efficiently integrate GeoGebra in Teaching Hyperbolic Geometry

To address challenges, courses of action are implemented. Students view the effective use of watching video tutorials as well as reaching hand to their classmates towards using GeoGebra. Moreover, familiarizing oneself with the features of the application will be easier for him/her to be used to it. Constant applying and using as well as exploring the application. Below are some excerpts of the responses of the participants regarding their steps on addressing the challenges they encountered along the way.

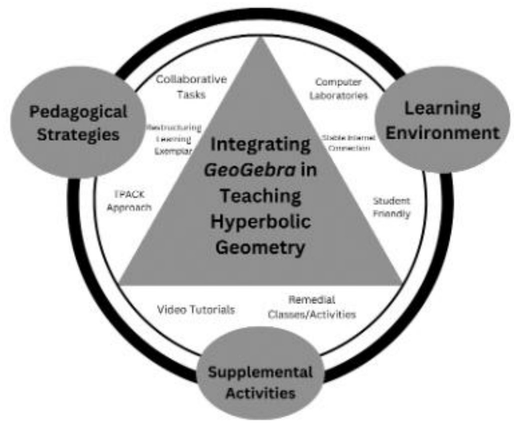
"*...I go to YouTube and watch video tutorials.*" – MM1 (Interview Transcript)

"*I explored GeoGebra and took some tutorials as well…*" –MM4 (Interview Transcript)

"*...familiarize yourself with the extensive tutorials…*" *–MM5* (Interview Transcript)

Proposed Intervention Model:

Figure 1. Integrating GeoGebra in Teaching Hyperbolic Geometry Intervention Diagram



The results predominantly show that GeoGebra is an important tool in promoting students' achievement and interest, supporting the studies of Granberg & Olsson (2015), Akanmu (2016), and Liu et al. (2011). This indicates that GeoGebra serves its primary purpose of providing visual representation of geometrical objects. It also corroborates the findings of Garber and Picking (2010), Ljajko et al. (2010), and Budai (2011), who noted that the application's visual representations enhance students' understanding of concepts. Additionally, Gittinger (2012) highlights that GeoGebra's dynamic tools offer clearer, tangible, and understandable graphs and representations. The findings suggest that if a student can visualize a problem, they are more likely to find solutions, prove or disprove hypotheses, and understand certain properties or theorems of Modern Geometry.

In terms of experience, most Math majors find the application's features challenging to use. According to McMahon (2015), knowing something is insufficient; one must be able to turn that knowledge and

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skills into practical solutions and applications. Today's generation is exposed to advanced technologies, making media and information literacy crucial. McMahon also noted that "the ability to regurgitate information is irrelevant unless you can do something with it." This highlights the idea that knowledge is meaningless without effective and efficient application. Analogously, no matter how useful, effective, and efficient GeoGebra's features are, they are not fully appreciated if someone does not know how to use them, which defeats the application's purpose.

Moreover, resources also affect the perception and utility of the application, as gadgets may offer different interfaces to end-users. Despite this, most math majors seek help from their peers and teachers to become accustomed to the application, aided by video tutorials. According to Lai, Zhu, and Williams (2016), learning through video tutorials can bring several benefits to students, such as enriching their learning experiences and, in turn, improving their academic performance. This suggests that visual teaching and tutoring are effective ways to help students understand concepts they may struggle with during lessons. Thus, an intervention model has been developed to ensure the effectiveness of integrating GeoGebra into class discussions in Modern Geometry, specifically in Hyperbolic Geometry.

Figure 1 illustrates the formulated interventions of the present study, identifying three key learning factors for effectively utilizing GeoGebra: the learning environment, pedagogical strategies, and supplemental activities. The university can enhance the learning environment by providing computer labs with GeoGebra installed and supported by a stable internet connection, creating a student-friendly and academically conducive setting. Pedagogical strategies can be improved by crafting lesson plans that effectively integrate GeoGebra into teaching modern geometry, particularly for proving theorems and properties in hyperbolic geometry. This includes incorporating collaborative tasks and continually developing Technological, Pedagogical, and Content Knowledge (TPACK). Additionally, supplemental activities such as video tutorials and remedial classes/activities can help students overcome challenges in using and familiarizing themselves with GeoGebra's features.

Conclusions

The purpose of this study is to develop interventions based on math majors' experiences with integrating GeoGebra into hyperbolic geometry instruction. Using a descriptive design, the researchers interviewed eight participants about their experiences with GeoGebra while proving theorems and properties in hyperbolic geometry. Students find GeoGebra beneficial if they are familiar with it and have full access to its features. However, many students performed only adequately in Modern Geometry due to difficulties with the application and its limited features, primarily because most students used mobile phones, which offer fewer capabilities than computers or tablets. The limited features and two-dimensional view on mobile phones can hinder understanding, especially in non-Euclidean geometries like hyperbolic geometry. This suggests the need for equal access to the application to avoid misconceptions and improve academic

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performance. Despite these challenges, GeoGebra successfully provided students with presentable outputs and increased their interest.

In addition to the previously mentioned obstacles, the use of GeoGebra as a learning and teaching supplement was also noted. Students reported that the application's limited functionality and effectiveness initially hindered their ability to fully master it. However, once they became proficient with its features, they found GeoGebra beneficial, as it presents outputs in a clear and understandable manner. This aids in the students' comprehension of problems and helps them acquire the required course competencies. Consequently, this finding suggests that GeoGebra is an excellent tool for enhancing academic achievement and interest, provided that students are familiar with the application and have the necessary resources. GeoGebra is particularly effective in online or distance learning environments.

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