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PRE-SERVICE TEACHERS' PERCEPTION OF THE USE OF GEOGEBRA IN TEACHING AND LEARNING GEOMETRY IN THE COLLEGES OF EDUCATION, GHANA: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The introduction of technology has given opportunities and made it easy for educators to utilize it in various ways, including in the field of education, as an instrument to support the teaching and learning of mathematics. GeoGebra is one of the mathematical software that can be effectively used in delivering mathematics lessons. GeoGebra is computer software that supports the teaching and learning of mathematics subjects, especially algebra, calculus, geometry, probability, and statistics. The objectives of this systematic analysis were to investigate pre-service teachers' perceptions and benefits of using GeoGebra to teach geometry. This study used a quantitative research design to review published articles from 2011 to 2021 related to the research objectives. This investigation purposefully sampled 17 published articles out of the over 200 articles found. The study used Google scholar, Google, and Sci Direct as the search engines to gather data using the keywords. The selected articles were validated using content analysis. This investigation selected the 17 articles for data analysis based on the research design, location, area of research, research focus and the type of technology applied. The findings of this study disclosed that pre-service teachers had the following perceptions regarding learning geometry with GeoGebra: GeoGebra enhances the teaching and learning of geometry, it helps learners to have positive perceptions concerning GeoGebra integration, GeoGebra improves learners' interest, motivation, and willingness to learn geometry. Also, it motivates learners to interact among themselves. Nevertheless, some benefits were identified as follows: GeoGebra increases students' academic performance, develops learners' confidence in learning geometry, makes the learning of mathematics enjoyable, and helps learners to conceptualize abstract concepts in mathematics. Based on the findings of this study, it is concluded that GeoGebra is effective for teaching and learning geometry. This study recommends that mathematics educators should embrace GeoGebra software in the teaching and learning of geometry at the college level of education. Additionally, the Ministry of Education should enforce the integration of GeoGebra in the delivery of mathematics lessons.

Keywords: mathematics, geometry, GeoGebra, perception, pre-service mathematics teachers

INTRODUCTION

Teaching and learning using technology have many merits including arousing learners' interest in learning mathematics, promoting lifelong learning, and enhancing pre-service mathematics teachers' participation, motivation, and performance. According to Zakaria and Khalid (2016), using technology to teach mathematics facilitates positive interaction and relationships among learners. However, research indicates that some college mathematics facilitators in Ghana do not integrate technology into their instructional process because of time constrain (Agyei & Voogt, 2011). The consequence of this is that pre-service mathematics teachers cannot integrate GeoGebra into the teaching and learning of mathematics. The use of GeoGebra in teaching and learning geometry can help learners to imagine, visualize and understand geometry concepts (Shadaan & Eu, 2013). Several technology tools are available such as Derive 5, Derive 6, Maple, MatLab, Geometer's sketchpad, calculator, and GeoGebra. Since all these technology tools cannot be considered at the same time, this paper focused on pre-service teachers' perception of utilizing GeoGebra in teaching and learning geometry at the College level of Education in Ghana. Further, we looked at the benefits of using GeoGebra to teach and learn geometry.

Furthermore, this section discussed the meaning of GeoGebra, geometry, perception, and pre-service teachers. Although many students believe that geometry is difficult and should not be included in the school curriculum, the use of GeoGebra can curb this allegation (Bowie, Venkat, & Askew, 2019). This software combines features of Geometers Sketchpad, Maple, and Derive (Saha, Ayub, & Tarmizi, 2010) as cited in (Shadaan & Eu, 2013). According to Hohenwarter and Lavicza (2009), GeoGebra is an open-source and user-friendly mathematics software that links algebra and geometry. GeoGebra is a transformative tool because it allows students to interact, manipulate and visualize. Majerek (2014) as cited in Chalaune and Subedi (2020) explained that GeoGebra is an action tool that can be used in teaching and learning algebra, calculus, geometry, probability, and statistics. GeoGebra can be obtained from the website https://www.geogebra.org/download. The researchers could not cover all these strands of mathematics because of the limited time. This study gravitated towards using GeoGebra to teach and learn geometry.

According to Tabak (2004), as cited in Naidoo and Kapofu (2020), geometry is the study of angles, dimensions, shapes, positions, and sizes of objects. Furthermore, Sunzuma, Masocha, and Zezekwa (2013) explained geometry as a field of mathematics that develops learners' spatial awareness, visualization, and enhances students' problem-solving skills. Also, Pesen (2006) as cited in Kakraba (2020) states that geometry is an area

of mathematics that develops students' deductive, critical, and logical reasoning skills. To conclude, geometry is a branch of mathematics that studies the properties of space that are related to the distance, shape, size, and relative position of figures.

Geometry is an integral part of our lives (Markovits & Patkin, 2020). According to Markovits and Patkin, we are surrounded by solids and shapes and interact with them every day. Children are used to solids and shapes. They play with these solids as children and use them for different games. Acquaintance with solids and shapes is very vital because they help young children to develop spatial orientation. Also, children establish the foundations for logical thinking when they play with solids and shapes while investigating the relationships between them. Despite the importance of geometry in our lives and schools, students develop a dislike for school geometry (Zutaah, Miheso-O'Connor, & Ondigi, 2022). To intervene in this situation, the present study investigated if the use of GeoGebra in teaching and learning geometry could boost pre-service teachers' perception concerning integrating GeoGebra into the teaching and learning of geometry.

From an academic perspective, perception concerns the way one sees the world (Mcdonald, 2011). Teachers usually use mathematics software that attempts to uncover and reframe learners' perceptions concerning geometry. This study focused on the use of GeoGebra to uncover and reframe pre-service teachers' perceptions concerning geometry. According to Perreault and McCarthy (2005), as cited in Amodu (2007), perception is the process by which we gather and interpret information from our surroundings. Perception is a process rather than an action because we constantly gather and interpret information from our surroundings. The perception of pre-service teachers about teaching and learning geometry is important in a teacher's ability to help young children develop an understanding of geometric concepts.

Finally, in this study, pre-service teachers refer to students enrolled in Ghanaian colleges of education who are undergoing training to become professional teachers. Training typically lasts four years. The terms pre-service teachers, college students, future teachers, and student teachers are used interchangeably in this study. Nonetheless, studies have been conducted in Malaysia and South Africa on secondary school students' perceptions of teaching and learning geometry using GeoGebra (Shadaan & Eu, 2013; Bayaga, Mthethwa, Bossé, & Williams, 2019). The current study's new focus was on Ghanaian college students. As a result, the goal of this study was to look into future teachers' perceptions of teaching and learning geometry in Ghana using GeoGebra. This study also looked at the advantages of using GeoGebra in teaching and learning geometry.

LITERATURE REVIEW

This section discussed the literature reviewed regarding the research objectives. The literature was reviewed based on the following research objectives: pre-service teachers' perceptions of integrating GeoGebra software into the teaching and learning of geometry, and the benefits of integrating the software into the instruction of geometry concepts. We would start with reviewing the literature on future teachers' perceptions of integrating the software in teaching and learning geometry because that is our first objective. Next, the review would be on the benefits of its integration in the delivery of geometry lessons.

Future Teachers' Perceptions of Integrating GeoGebra in Teaching and Learning Geometry

There are many mathematics software such as geometers sketchpad, maple, and GeoGebra available for teaching and learning geometry in particular and mathematics generally at all levels of education. The software act as a teaching and learning resource for both teachers and learners. Mathematical software helps to motivate learners to study geometry. Many students dislike geometry because they claim geometry concepts are abstract and difficult to understand. Importantly, Ubi and Odiong (2018) established that geometry is hard and disliked by many students. As Ubi and Odiong have convincingly shown in their research, students perceive geometry as difficult because of limited timing, irregular class practices, unavailability, and inappropriate use of teaching and learning materials. To fill up this gap, this study focused on using GeoGebra out of the lot to investigate pre-service teachers' perceptions concerning geometry because GeoGebra is available and free to download from the website.

Globally, Shadaan and Eu (2013) investigated if the use of GeoGebra could help secondary school students solve problems in circles. The study employed a quasi-experimental design. It was disclosed that there existed a significant difference in the mean scores between students in the experimental and control groups in favor of the experimental group. The result clearly shows that GeoGebra has improved secondary school students' performance in circles. Based on this finding, it is important to state that GeoGebra is effective in teaching and learning mathematics. We vehemently agree with the findings of Shadaan and Eu (2013) because the constructivist theory used in the study promoted interaction among students and concept visualization. However, this investigation focused on college students who are receiving training to become professional teachers in Ghana though Shadaan and Eu's (2013) study was on secondary school students in Selangor.

Furthermore, Segal, Oxman, and Stupel (2021) investigated pre-service mathematics teachers' pedagogical and technological knowledge in transformation. The study included twenty-seven future teachers studying to become professional teachers. The students were assigned to experimental and control groups. Students in the control group learned transformation using conventional methods such as using paper and pencil. Nevertheless, participants in the experimental group studied transformation using GeoGebra. The results revealed that the majority (more than 80%) of future teachers indicated that GeoGebra is a good instructional software for revising and expanding students' knowledge in transformation. This indicates that the GeoGebra software had a positive influence on students' achievement and perception of learning transformation. The researchers acknowledge the findings because GeoGebra might promote pre-service mathematics teachers' visualization of concepts. The present study assessed college students' perceptions toward integrating GeoGebra into the instruction of geometry lessons.

Moreso, Dağ, Şumuer, and Durdu (2019) assessed pre-service mathematics teachers' perceptions of geometry concepts using GeoGebra in Turkey. Eighty pre-service teachers participated in the study. The study established that participants demonstrated positive perceptions toward GeoGebra integration. This outcome established that the software allowed learners to visualize geometric concepts and interact among themselves. GeoGebra has positively changed PMTs' perceptions of using the software to teach geometry concepts. As Dağ et al. (2019) show in their research, GeoGebra has positively influenced students' perceptions and experiences regarding teaching and learning using the software. The present study supports the findings of Dağ et al. (2019) because GeoGebra might play a role in motivating learners to share knowledge of geometric concepts. Although Dağ et al. (2019) study was in Turkey, the present study was in Ghana.

In Africa, Mulder (2017) investigated pre-service mathematics teachers' perceptions concerning integrating technology in the delivery of mathematics lessons. Seven future teachers were used for the investigation. The findings indicated that pre-service teachers feel the confidence to utilize technology in the instructional process. The participants pointed out that there was pressure on them when integrating technology into teaching. This shows that GeoGebra is a powerful tool that supports both mathematics educators and learners. However, its application needs constant practice to avoid learners' confusion. As Mulder (2017) has convincingly shown in his work, pre-service teachers feel a sense of pressure to be able to teach using technology. This investigation agrees with Mulder's findings because many teachers are not comfortable

teaching using technology. Even though Mulder (2017) used technology in general the present study investigated the GeoGebra application.

Again, Mokotjo and Mokhele-Makgalwa (2021) conducted a study on South African mathematics educators' perceptions of the value of GeoGebra integration in the mathematics classroom. The study included four secondary school teachers. The finding revealed that mathematics teachers are enthusiastic about applying GeoGebra to teach mathematics. Mathematics educators believed that the software was valuable in teaching mathematics. This finding indicates that the software empowered the teachers and learners in the instruction process which made a significant impact on students' achievement in mathematics. Similarly, Horzum and Ünlü (2017) investigated mathematics teachers' perceptions of GeoGebra and its use. The study reported that the majority (more than 85%) of mathematics teachers agreed to use GeoGebra in teaching mathematics. This study strongly agrees with the outcome of Horzum and Ünlü (2017) because the software had a positive influence on mathematics teachers' perception of learning mathematics. The new angle of the present study was in Ghana while Mokotjo and Mokhele-Makgalwa (2021) was conducted in South Africa.

In Ghana, Salifu (2020) investigated college students' perceptions toward integrating GeoGebra in the learning of the circle theorem in the Northern sector of Ghana. The study used eighty-eight college students. The findings indicate that participants who studied the circle theorem with the software showed positive interest in teaching utilizing GeoGebra. This shows that GeoGebra software had a positive impact on students' performance and perception regarding the learning circle theorem. The findings of Salifu are in line with Shadaan and Eu (2013) who investigated the effectiveness of using GeoGebra on secondary school students' ability to solve problems concerning circles. Based on these findings, there is sufficient evidence to conclude that GeoGebra is an enabler that promotes the instruction of geometric concepts for example, and mathematics as large. Although the present investigation is a review article, that of Salifu (2020) is an original research article.

In summary, studies including Shadaan and Eu (2013) have been conducted on secondary school mathematics teachers using GeoGebra. Nevertheless, the extent to which the application of the software is proven to enhance mathematics teaching among high school teachers. Therefore, the first objective of the present study investigated future teachers' perceptions of utilizing GeoGebra in the instruction of geometry among college students.

Benefits of Utilizing GeoGebra in Geometry Instruction

There are many benefits of teaching and learning geometry with GeoGebra. Many researchers have conducted studies in this area. Let us look at the findings of the various researchers as follows:

Globally, Zakaria and Khalid (2016) investigated the importance and challenges of utilizing Information and Communication Technology (ICT) in mathematics lessons. Zakaria and Khalid reviewed twenty articles. As seen by Zakaria and Khalid (2016), it was established that the application of ICT in the instruction of mathematics is beneficial in the following ways: ICT attracts students' interest in learning mathematics, it increases students' motivation and achievement, it promotes lifelong learning, as well as facilitates positive students interaction and relationships. This shows that teaching and learning mathematics utilizing technology promotes active participation and relational learning. In some cases, if proper supervision is not done by the teacher, learners will end up playing with the resource instead of learning. However, GeoGebra decreased the cognitive load during students learning because it makes concepts clearer. The present study focused on pre-service teachers' perceptions of using GeoGebra to be specific in teaching geometry but not ICT as in the case of Zakaria and Khalid (2016).

In addition, Alkhateeb and Al-Duwairi (2019) assessed the influence of utilizing Sketchpad and GeoGebra on high school pre-service teachers' performance in geometry. One hundred and five (105) students were included in the study. The study was conducted in Jordan. Findings indicated that the use of the software enabled learners to solve problems in geometry. Though Alkhateeb and Al-Duwairi found GeoGebra to be more effective than the sketchpad on student learning, the researchers are not surprised because GeoGebra is more interactive as compared to the sketchpad. On the other hand, a sketchpad is more effective in learning sketches. GeoGebra is a powerful action tool that can support the teaching and learning of algebra, geometry, calculus, probability, and statistics. As Hohenwarter and Lavicza (2009) showed in their research, GeoGebra has an algebra view, calculus view, geometry view, probability, and statistics view. Hence, GeoGebra is suitable for teaching in these areas of mathematics. Whereas Alkhateeb and Al-Duwairi (2019) used high school teachers as the study sample, the present study focused on basic school pre-service teachers who will be teaching in basic schools after completion.

Also, Celen (2020) assessed secondary school students' views on integrating GeoGebra software in instructing geometry lessons. The study used fourteen students in Turkey. The study revealed that the software promotes mathematics learning. Again, the finding showed that GeoGebra helps students in concretizing abstract concepts in mathematics. This shows that GeoGebra helps learners to solve problems concerning

geometric concepts which results in students' academic achievement. The implication is that mathematics educators should use GeoGebra in the mathematics classroom. The present study acknowledges the findings of Celen (2020), however, students with low computer literacy can have difficulties in applying GeoGebra activities. Zakaria and Khalid (2016) pointed out that low computer literacy is one of the constraints in learning mathematics using technology. The new angle of the present study is in Ghana but Celen (2020) was in Turkey.

In Africa, Bayaga et al. (2019) assessed the impact of implementing GeoGebra software on students learning of geometry. The investigation was carried out on one hundred and twelve (112) South African senior high school students. The study observed a statistically significant effect on students learning geometry. The analysis of the questionnaire items also reported that students appreciated the use of GeoGebra in learning geometry. These findings show that GeoGebra is capable of enhancing students' academic achievement in geometry. Again, it is important to state that GeoGebra motivates learners in the teaching and learning process. This implies mathematics instructors should employ the software in mathematics classrooms. The use of GeoGebra can encourage interaction among students leading to high academic achievement. However, the study of Bayaga et al. (2019) was conducted on high school students in South Africa while the present investigation focused on future mathematics teachers in the colleges of education in Ghana.

In addition, Wassie and Zergaw (2019) investigated the importance and challenges of using GeoGebra in a mathematics classroom in Ethiopia. Forty (40) articles were reviewed. The findings showed that GeoGebra increases students' interest and achievement in mathematics. This result shows that GeoGebra helped learners to actively participate in the teaching and learning process. The implication is that mathematics educators would be willing and frequently use the software in their mathematics lessons. While the study by Wassie and Zergaw (2019) was carried out in Ethiopia, the focus of the present study was in Ghana. GeoGebra is an action tool that fosters students' interest and achievement in mathematics. Tamam and Dasari (2021) conducted a reviewed literature study and reported that GeoGebra helps learners to solve problems in geometry.

Another study conducted by Mwingirwa and Miheso O'Connor (2016) assessed Kenyan high school mathematics educators' perspectives concerning teaching with GeoGebra. Findings indicated that GeoGebra motivated high school teachers to show a willingness to teach mathematics with GeoGebra. This means that GeoGebra empowered both teachers and learners in the teaching and learning of mathematics. It was disclosed that GeoGebra is a powerful mathematics software that is capable of attracting teachers' interest to employ the software in teaching mathematics. Though Mwingirwa and Miheso

O'Connor (2016) carried out their investigation on senior high school practicing teachers in Kenya, the present study focused on college students in Ghana who are receiving training to become professional teachers. These future teachers will be teaching in basic schools after completion.

In Ghana, Badu-Domfeh (2020) assessed the impact of GeoGebra integration in the instruction of circle theorem among senior high school students. The study included seventy-eight participants in the Bono Region of Ghana. The findings indicated that GeoGebra software enhances students' performance in geometry. Again, the software was found to be boosting students' interest to learn geometry to be specific and mathematics in general. This outcome indicates that the software is an action tool in increasing learners' performance in geometry to be specific and mathematics in general. This implies both mathematics teachers and learners are willing and will frequently use the software in the mathematics classroom. Based on the outcome of Badu-Domfeh (2020), it is important to conclude that GeoGebra is a mathematics tool that can improve students' performance in geometry for example, and mathematics in general. This implies GeoGebra software promotes learners' academic performance and attitude regarding the learning of geometry. The present study focused on college students' perceptions of using GeoGebra to learn geometry in the colleges of education while Badu-Domfeh (2020) was conducted on secondary school students.

To summarize, studies including Badu-Domfeh (2020) have been conducted on senior high school students. Nevertheless, the extent to which the application of the software is proven to improve learners' performance in mathematics. Therefore, the focus of the present study is on college students.

Geometry helps learners to relate concepts in the classroom to the real world. Additionally, it is a fundamental course for learners to learn other branches of mathematics. Furthermore, geometry helps learners to visualize abstract concepts in mathematics. On the other hand, inadequate knowledge of pre-service mathematics teachers in geometry would make them unable to relate concepts in the classroom to the real world. Again, they would not be able to visualize abstract concepts in mathematics. Despite the importance of geometry to learners, college students in Ghana perceive geometry as difficult (Zutaah et al., 2022). Although the teacher delivers the expected knowledge to help students understand geometry concepts, students seem not to like solving tasks concerning geometry. Something more may be needed to guide students to develop an interest in geometry. As Shadaan and Eu (2013) aptly show where pre-service teachers faced challenges in studying geometry and many demonstrated a dislike for geometry as a subject.

GeoGebra can play a role in filling up the gap by helping pre-service teachers to visualize and develop an interest in geometry through exploration. Also, using GeoGebra could have a positive influence on students' perception of geometry. Therefore, this study investigated if the use of GeoGebra could have an impact on pre-service teachers' perception of geometry. Further, the study assessed the benefits of integrating GeoGebra into the teaching and learning of geometry.

RESEARCH QUESTIONS

This paper was guided by the following questions:

a) What are pre-service teachers' perceptions of using GeoGebra to teach and learn geometry?
b) What are the benefits of using GeoGebra to teach and learn geometry?

RESEARCH METHODOLOGY

In this section, we discussed the research methodologies that were used in the study. This study used a quantitative research design to collect and analyze the data. This investigation highlights studies conducted in the field of applying GeoGebra in teaching and learning geometry. This review article was carried out to collect information on future teachers' perceptions concerning integrating GeoGebra in the delivery of mathematics lessons from previous investigations on geometry. This investigation used Google Scholar, Google, and Sci Direct to search the information using the following keywords: pre-service teachers' perceptions of utilizing GeoGebra to deliver geometry lessons; and the benefits of teaching geometry with GeoGebra. The present study used these tools because they are the leading databases that consist of bibliographic documents with full-text articles in various disciplines, especially for educational multidisciplinary research (Aliyu, Osman, Daud, & Kumar, 2021). The literature was chosen in the English Language. Furthermore, this study used scholarly works from 2011 to 2021 related to geometry instruction utilizing GeoGebra software. All articles before 2011 were excluded from the examination. Even though the GeoGebra software was developed in 2001 by Markus Hohenwater, the 2011 to 2021 duration was chosen to enable the researchers to obtain current information concerning the research objectives. This investigation found more than two hundred (200) published articles on integrating technology into teaching and learning mathematics. Notwithstanding, this investigation utilized seventeen (17) studies from Ghana, Africa, and Abroad to analyze the data concerning the research focus: pre-service teachers' perceptions and benefits of teaching geometry with GeoGebra. This study selected 17 out of 200 articles that are scholarly works, have full–text, and are peer-reviewed using the Mendeley library online. Furthermore, this study considered the

scope, the respondents involved, and the context of the study to draw the articles for the study. See Figure 1 below for the summary of the selection process of the 17 published articles for data analysis.

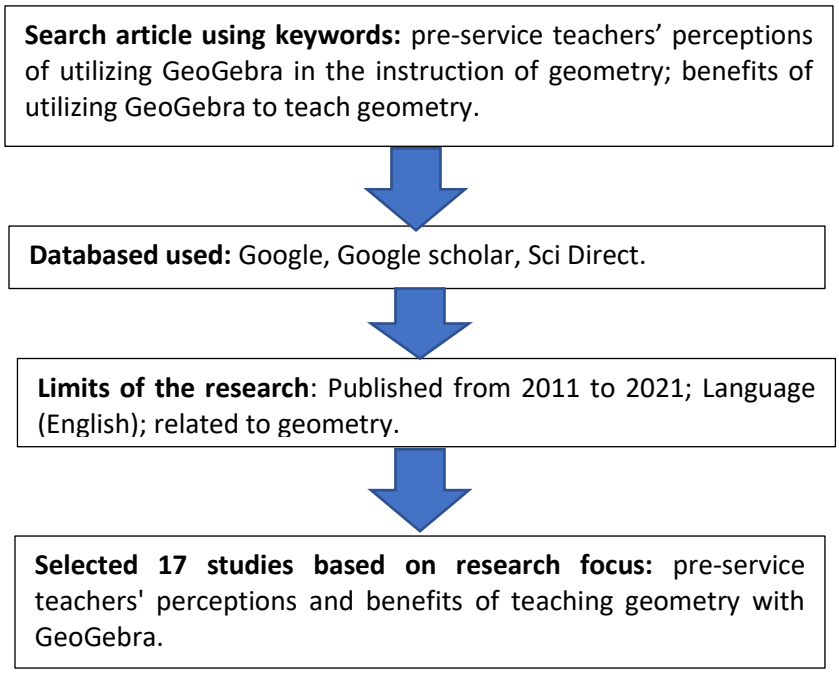

Figure 1. The Selection Procedure of 17 Articles for Data Analysis

Moreso, Table 1 below gives the summary of the 17 selected articles for data analysis. The summary considered the research design, location, research focus, area of research, and the application of the software used. The findings of the selected published articles helped this study to gather data to respond to the research questions. Also, this investigation checked the validity of the selected articles utilizing the content analysis to obtain the required information for the study.

Table 1. Summary of Seventeen Articles Selected for Data Analysis

Research Design	Location	Research focus	Area	Software
Quasi-experimental (9)	Abroad (8)	Educators (4)	Mathematics (8)	Sketchpad (1)
Mixed-method (1)	Africa (6)	Students (13)	Geometry (9)	GeoGebra (15)
Qualitative (5)	Ghana (3)			ICT (1)
Concept paper (2)				

A look at Table 1 above shows that this study used 17 articles in the data analysis of which nine (9) of them used a quasi-experimental design, one (1) mixed method design, five (5) qualitative design, and two (2) concept papers. Again, out of the 17 articles, eight

were conducted Abroad, six were in Africa, and three of them in Ghana. Furthermore, Table 1 indicates that out of the seventeen articles, four of them focused on mathematics educators while thirteen of them focused on students. Also, eight of the seventeen articles were in the area of mathematics in general and the remaining nine were in the area of geometry specifically. Finally, among the seventeen articles, one of the studies used sketchpad software, fifteen of them used GeoGebra software, and the remaining one used ICT.

Finally, to answer the research questions, this study analyzed the data using descriptive statistics from SPSS, such as mean and percentages and reported the results in tables. Garth (2008) states that descriptive statistics are used in SPSS to respond to research objectives, while kappa analyses are used to test the hypothesis. The kappa analysis is used to determine whether two raters agree or disagree. According to Garth (2008), because this study used research objectives, descriptive statistics such as the mean and percentage were used to answer the research questions.

RESULTS AND DISCUSSIONS

Here, we discussed the study findings. This investigation presented the findings according to the research questions. First, the discussion was on future teachers' perceptions of teaching geometry utilizing GeoGebra. Second, this study discussed the findings on the benefits of integrating GeoGebra into the instruction of geometry.

Future Teachers' Perceptions of Integrating GeoGebra in Geometry Instruction

This study assessed future mathematics educators' perceptions of integrating GeoGebra software into the instruction of geometry to answer research objective one (1). Out of the 17 articles reviewed, the outcome of 10 of the articles was a response to research objective 1. Based on the analysis of the 10 articles, the findings are presented in Table 2 below.

Table 2. Pre-service Teachers' Perceptions of Using GeoGebra in Teaching and Learning Geometry

Theme	Number	Percent (%)
GeoGebra enhances the teaching and learning of geometry	3	30
GeoGebra helps learners to have positive perceptions concerning GeoGebra integration	1	10
GeoGebra improves learners' interest, motivation, and willingness to learn geometry	5	50
GeoGebra motivates learners to interact among themselves	1	10
Total	10	100

A look at Table 2 above indicates that pre-service teachers have the following perceptions toward integrating GeoGebra into the instruction of geometry. Three of the studies representing 30% indicate that GeoGebra enhances the teaching and learning of geometry, one (1) representing 10% shows that GeoGebra helps learners to have positive perceptions concerning GeoGebra integration, five articles representing 50% established that GeoGebra improves learners' interest, motivation and willingness to learn geometry. Again, one article representing 10% reported that GeoGebra motivates learners to interact among themselves. This result shows that GeoGebra is powerful computer software that can improve learners' academic achievement in geometry and build their confidence as well as their interest to learn mathematics. This implies mathematics educators and learners are willing and would frequently use the software in the mathematics classroom.

The outcome of this investigation established that the software promotes future mathematics teachers' understanding of mathematical concepts. Again, GeoGebra empowered mathematics instructors and learners in the delivery of mathematics lessons. The study findings are in line with that of Agyei and Benning (2015) who investigated future teachers' perceptions of GeoGebra software as an instructional tool for mathematics lessons. Agyei and Benning (2015) found that GeoGebra increased participants' willingness and frequency to use the software in their future mathematics classrooms. Similarly, Segal et al. (2021) investigated pre-service mathematics facilitators' perceptions of using Geogebra in delivering concepts in transformation and reported that the software is a useful instructional tool for expanding learners' knowledge in transformation. This shows that GeoGebra is effective in the teaching and learning of geometry in particular and mathematics in general. The implication is that mathematics educators and learners should embrace the use of the software as an instructional tool

for mathematics. The use of GeoGebra can encourage active participation among learners to share knowledge and skills. Indirectly, this increases students' performance in geometry in this case and mathematics in general.

Furthermore, the findings of this investigation show that pre-service teachers are willing and would frequently use GeoGebra in their mathematics classrooms. This is supported by the finding of Belgheis and Kamalludeen (2018) who investigated mathematics teachers' intention to use GeoGebra in teaching mathematics in Malaysia. The study of Belgheis and Kamalludeen (2018) used a quasi-experimental design. A workshop was organized for mathematics teachers where some were trained using GeoGebra and others using the traditional method. The study observed a significant difference between participants in the experimental and control groups in their intention to use the software in their mathematics classrooms favoring the participants in the experimental group. Based on the finding of Belgheis and Kamalludeen (2018), there is sufficient evidence to state that GeoGebra is an action tool that boosts mathematics teachers' and learners' interest to use it in the mathematics classroom.

Also, the outcomes of the present investigation are in line with that of Horzum and Ünlü (2017) who assessed future teachers' opinions concerning GeoGebra and its use. It was established that all participants mentioned that GeoGebra has positive effects on their professional development. Again, all participants stated that the software can improve learners' academic performance in geometry. Finally, the findings indicate that all participants concluded that they would like to utilize the software as an instructional tool in the mathematics classroom. This shows that GeoGebra is an effective instructional tool that can empower educators and learners in the instruction of mathematics lessons. This implies that future teachers believed that the software enhances the teaching and learning of geometry concepts.

Moreso, this study's findings support that of (Alkhateeb & Al-Duwairi, 2019; Badu-Domfeh, 2020; Salifu, 2020; Shadaan & Eu, 2013; Wassie & Zergaw, 2019; Zakaria & Khalid, 2016) who reported that pre-service teachers mentioned that GeoGebra improves students academic performance in mathematics. The use of GeoGebra promotes active participation among learners to share knowledge and skills. Indirectly, this increases students' performance in geometry. Similarly, the findings from two studies revealed that GeoGebra promotes a positive perception of using GeoGebra in learning geometry when students were allowed to interact among themselves (Shadaan & Eu, 2013; Dağ et al., 2019). Indirectly, the active participation among learners during the instructional process enhanced knowledge sharing.

Additionally, the findings of this investigation established that GeoGebra has provided a valuable instrument for revising and expanding pre-service teachers'

knowledge in transformation. This finding supports (Segal et al., 2021). This means that GeoGebra is a powerful mathematics action tool that can build confidence in future teachers to integrate technology into the instruction of geometry. This supports the constructivist theory which emphasizes the use of technology, social interaction, and self-exploration to promote an understanding of geometry concepts. Indirectly, future teachers' understanding leads to their confidence to integrate GeoGebra in the teaching and learning of geometry concepts.

Finally, this study's findings established that pre-service mathematics teachers showed positive interest in instructing mathematics using GeoGebra, mathematics educators believed that GeoGebra could promote their enthusiasm, and increase students' motivation. These findings are supported by that of (Mokotjo and Mokhele-Makgalwa, 2021; Salifu, 2020; Zakaria & Khalid, 2016).

Based on the outcomes of this investigation, there is sufficient evidence to conclude that GeoGebra is an effective instructional tool for teaching and learning geometry in particular and mathematics in general. Also, GeoGebra can improve student academic achievement.

Benefits of Integrating GeoGebra in Geometry Lessons

Research has revealed some advantages of integrating GeoGebra software into the teaching and learning of geometry. This study investigated the benefits of integrating GeoGebra into the teaching and learning of geometry to answer research objective 2. The outcome of the analysis of 7 out of the 17 articles responded to research objective 2. The findings from the 7 published articles are summarized in Table 3 below.

Table 3. Importance of Teaching Geometry with GeoGebra

Theme	Number	Percent (%)
GeoGebra increases students' academic performance	3	42.8571
GeoGebra develops learners' confidence in learning geometry	2	28.5714
GeoGebra makes the learning of mathematics enjoyable and fun	1	14.2857
GeoGebra helps learners to conceptualize abstract concepts in mathematics	1	14.2857
Total	7	100

From Table 3 above, 3 (42.8571%) studies indicate that GeoGebra increases students' academic performance, 2 (28.5714%) disclosed that GeoGebra develops

learners' confidence in learning geometry, 1 (14.2857%) show that GeoGebra makes the learning of mathematics enjoyable, and fun. Additionally, 1 (14.2857%) revealed that GeoGebra helps learners to conceptualize abstract concepts in mathematics. This outcome indicates that GeoGebra software is a powerful instructional software that is capable of improving learners' academic achievement. This implies that mathematics instructors and learners would accept GeoGebra integration in the mathematics classroom.

The findings of this investigation are in agreement with that of Alkhateeb and Al-Duwairi (2019) who reported that Sketchpad and GeoGebra helped learners solve geometry concepts. Also, according to the findings of Alkhateeb and Al-Duwairi (2019), GeoGebra had more effect than sketchpad on learners' academic achievement. This shows that both software is good for teaching geometry but GeoGebra seems to be more interactive than a sketchpad. Based on the findings of Alkhateeb and Al-Duwairi (2019), there is enough evidence to state that GeoGebra has more effect in delivering geometry concepts.

Furthermore, these findings concur with the research by Dahal, Shrestha, and Pant (2019) who conducted a study on the impact of GeoGebra and students' performance in transformation concepts. The finding indicates that GeoGebra is useful in improving students' academic achievement in transformation concepts. Based on the finding of Dahal et al. (2019), it makes sense to state that GeoGebra is important educational software that supports mathematics instruction.

Moreso, it was disclosed from the findings of this study that GeoGebra improves students' performance in geometry in this case and mathematics in general. This finding is supported by that of Mukamba and Makamure (2020) who researched integrating GeoGebra into the instruction of geometric transformation and found that GeoGebra improved learners' performance in geometric transformation more than those who learned geometry using the traditional methods. This shows that GeoGebra helped participants who learned geometry using the GeoGebra to understand geometric concepts more than their counterparts who learned the same concepts using the traditional method. According to the outcome of this research, it makes sense to state that GeoGebra is an effective instructional mathematics software for increasing the mastery and retention of mathematics concepts.

Also, the findings of this investigation established that GeoGebra increases students' academic performance in geometry. This outcome concurs with that of Bayaga et al. (2019) who reported that GeoGebra had a statistically significant effect on the students to correctly complete problems concerning some circle geometry. In addition to GeoGebra helping students to complete problems regarding circle geometry, it made

students appreciate it in the mathematics classroom. The GeoGebra software motivated learners to keep solving mathematics questions until the correct answers were obtained. Indirectly, this method might have increased students' motivation and interest to keep trying.

Finally, these findings of the present study support that of (Badu-Domfeh, 2020; Celen, 2020; Chalaune & Subedi, 2020; Wassie & Zergaw, 2019) who have convincingly shown in their research that GeoGebra makes students conceptualize abstract concepts in mathematics. This shows that GeoGebra serves as a scaffold to enhance students' understanding of geometry concepts specifically and mathematics in general. In the GeoGebra environment, students are allowed to explore, visualize, and interact among themselves to share knowledge. From this perspective, the teacher acts as a facilitator. However, it seems reasonable to state that students with low computer literacy might have difficulties in applying GeoGebra activities. Based on the findings of this investigation, there is sufficient evidence to state that GeoGebra is a powerful mathematics software for both teachers and students in teaching and learning mathematics.

Conclusion

This research observed that pre-service teachers had the following perceptions regarding learning geometry using GeoGebra: GeoGebra enhances teaching and learning of circles, encourages positive interaction among students, promotes positive perception regarding the use of GeoGebra, perceived GeoGebra as a valuable instrument, promotes students' enthusiasm, as well as increases students' motivation, interest, and lifelong learning.

However, the use of GeoGebra is important in the following ways: GeoGebra enhances students' performance in geometry, makes the learning of mathematics fun and enjoyable, facilitates students to conceptualize abstract concepts in mathematics, and builds pre-service teachers' confidence to teach and learn geometry to be specific and mathematics in general.

Recommendation

Regarding the outcome of the analysis of the selected studies, the following suggestions were made:

a) Mathematics educators should increase the amount of training for pre-service mathematics teachers regarding GeoGebra integration.
b) It is proposed that the Ministry of Education should enforce GeoGebra integration in the teaching and learning of mathematics in colleges of education in Ghana.

Moreso, this study suggested further studies in the following ways:

a) Further study should be carried out on future mathematics educators' perceptions of utilizing GeoGebra in teaching and learning algebra, calculus, trigonometry, and statistics.
b) Since this research investigated the benefits of using GeoGebra in instructing geometry, it is suggested that a further study should be conducted on the challenges of integrating GeoGebra into geometry lessons at the college level of education.

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Author contributions

All authors have sufficiently contributed to this study and agreed with the results and conclusions.

Declaration of Interest

All the authors declared no conflict of interest.

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