The Cognitive and Non-Cognitive Effects of Geogebra Integration

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Abstract

Geogebra was known as an interactive mathematics software and environment that supported a variety of mathematical activities, making it ideal for learning and teaching Science, Technology, Engineering, and Mathematics (STEM). The study investigated the integration of geogebra into a geometry curriculum and its effects on cognitive and non-cognitive aspects. Using mixed-method research, the study examined the impact of geogebra on student test performance, engagement, and motivation. The research participants were BSED mathematics students enrolled in plane and solid geometry. The respondents were chosen without using a random selection procedure. An adapted questionnaire was used to assess the level of mathematics engagement and motivation, while a researcher-created questionnaire was used to assess the level of test performance. The quantitative part utilized the mean, percentage, Wilcoxon-signed ranked scale, and Spearman rank-order correlation. Jack Caulfield's six-step thematic analysis was used to assess the qualitative aspect. The findings indicated that incorporating geogebra benefited student engagement and test performance; however, students' motivation remained the same. The data also revealed a positive relationship between engagement and motivation and a non-significant correlation between engagement and test performance, as well as motivation and test performance. The study showed that students encountered various challenges when using geogebra. The use of the proposed enhancement of technology-aided instruction to improve geometry teaching and learning was suggested. Finally, this study provided evidence that geogebra could effectively be used to increase student engagement and motivation.

Keywords: geogebra; cognitive and non-cognitive effects; engagement; mathematics motivation; test performance.

1 Introduction

The assumption was that Information and Communication Technologies (ICT) integration in education could not replace a teacher; hence, teachers had to be equipped with both content knowledge and the ability to effectively apply technologies to facilitate teaching and learning processes that led to student achievement and Higher-Order Thinking Skills (HOTS) [27, 13, 14]. This underlined the importance of teachers presenting courses in a way that piqued students' interest in the learning process through technology integration, highlighting teachers as the best visual aid in the classroom. One of the most prevalent classroom challenges students confronted was dealing with mathematics. Students observed it as difficult to understand, which caused them to lose interest and focus on understanding the mathematical topic. Designing a session where students could participate in classroom discussions utilizing technology was one technique to stimulate students' interest in mathematics education. Geogebra could be used as an ICT learning tool in the research.

Geogebra was known as an interactive mathematics software and environment that supported a variety of mathematical activities, making it ideal for learning and teaching Science, Technology, Engineering, and Mathematics (STEM). It provided a platform for graphing, dynamic 2D as well as 3D geometry, interactive and symbolic algebra, excel sheets, probability, complicated numbers, equations involving differentials, interactive text, and more [7]. Visuals could be used in the software to illustrate mathematical concepts, assisting students in learning and mastering the topics. Geogebra improved student learning and experience by allowing students to find, visualize, and create mathematical concepts [20]. Teachers could improve students' understanding and engagement with subject matter by adapting strategies such as creating an engaging environment, encouraging cognitive engagement, and hands-on learning, resulting in improved concentration levels, increased student interest, and better learning outcomes.

The pre-service teachers in the BSED mathematics program at the College of Teacher Education had to learn to effectively use various instructional strategies and technologies to teach mathematics. Geogebra was one such technology that was gaining traction in mathematics education. The Geogebra Institute of Manila, the Philippines' first geogebra institute, provided a platform for teacher education students to learn how to use geogebra in mathematics teaching and learning. Despite this technology being available, the university offering the BSED mathematics program still needed to integrate geogebra into its curriculum fully. This lack of integration prompted a study to introduce geogebra to BSED mathematics students and evaluate its effectiveness as a teaching and learning tool. The study served as a springboard for the university, specifically the College of Teacher Education, to give students hands-on experience with geogebra in their maths classes. Finally, the study introduced geogebra to BSED mathematics students in their geometry classes and observed their use of the software in their teaching and learning activities. Geogebra integration in the curriculum had the potential to improve student's learning and provided them with valuable technological skills that they could apply in their future teaching practices.

As ICT evolved, new teaching tools became more prevalent and could be used in various ways to improve and enhance mathematics instruction [29]. Condori et al. [19], said that the degree of understanding was relatively high when using geogebra to learn geometry. The study concluded that the software generated a high level of interest and motivation in pedagogical activities and that the usage of geogebra resulted in a high degree of adequate understanding in the development of geometry. This was consistent with the most recent study on geogebra, which found that using geogebra to boost mathematical learning was highly recommended since it made mathematics learning more entertaining and exciting [25]. In addition, the findings of the research indicated that the academic achievement and motivation scores of the experimental group were significantly

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higher than those of the control group [9].

Based on previous research, results, and findings, it was discovered that integrating geogebra in teaching mathematics, notably in geometry, raised the students' performance level. Only the cognitive component of integrating geogebra as a technique to improve mathematics instruction was noted by Zilinskiene & Demirbilek [29]. Condori et al. [19], Selvy et al. [25], and Zahra et al. [9], stated that the student's interest and motivation determined the level of understanding of mathematics learning. The findings focused solely on determining the level of understanding and do not consider the students' motivation and engagement in using geogebra. More research on this topic was needed to acquire a comprehensive knowledge of how geogebra influences cognitive and non-cognitive components of students, given the research invalidation in this area.

As a result, this study aimed to address that gap by assessing and evaluating students' levels of mathematics engagement, motivation, and test performance before and after the incorporation of geogebra in studying geometry. Additionally, the study determined how geogebra was being integrated into the teaching and learning process. Furthermore, the study expanded its investigation into the students' experiences while learning geometry with geogebra. After determining the cognitive and non-cognitive effects of utilizing geogebra in learning geometry, the study proposed an enhancement of technology-aided instruction to satisfy the students' needs and improve the teaching and learning process.

2 Theoretical-Conceptual Framework of the Study

The engagement theory of learning, developed by Greg Kearsley and Ben Schneiderman was the foundation for this research. The theory emphasized the importance of active cognitive processes in student engagement. This revolved around three core elements: relating, creating, and donating [11]. Relating involved collaborative learning, where students shared perspectives and connect with their peers. Creating focused on project-based learning, allowing students to take ownership of their learning by engaging in innovative and purposeful activities. Donating referred to external, real-world learning, where students contributed to the needs of a third party or organization. By incorporating these principles into the learning environment, students were naturally motivated to learn and find meaning in their educational experiences.

Geogebra was being introduced as an ICT tool in teaching and learning to help students become more interested in geometry learning and assess the cognitive (test performance) and non-cognitive (mathematics engagement and motivation) components. Figure 1 showed the schematic diagram of the study. The engagement theory stated that students learn better when actively involved in the learning process. BSED mathematics students were being introduced to mathematics learning software using this theory.

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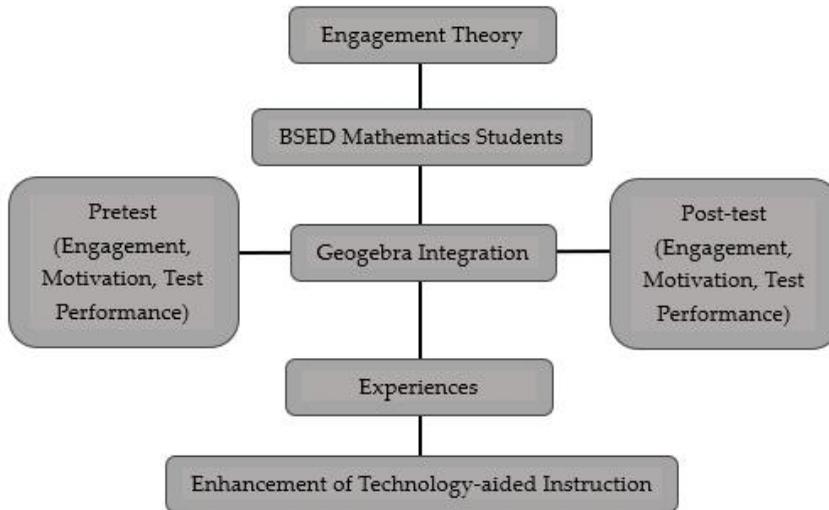*Malaysian J. Math. Sci. 18*(2): 423–443 (2024) *423 - 443*

Figure 1: The schematic diagram of the study.

During the pretest, students answered a questionnaire to determine their level of engagement, motivation, and test performance. Geogebra was then integrated into the discussion of geometry for two to three months to provide students with interactive and engaging learning experiences. The students were re-evaluated with the same questionnaire during the posttest to assess the level of engagement, motivation, and test performance. Based on the experiences, students were asked what they liked most and least about geogebra integration. Finally, based on the findings, an enhancement of technology-aided instruction was proposed.

3 Objectives

This study determined the cognitive and non-cognitive effects of using geogebra in learning geometry among BSED mathematics students at the University of Cebu Lapu-Lapu and Mandaue. Specifically, it sought to answer the following questions:

1. What are the students' engagement, motivation, and performance levels before integrating geogebra as a tool in learning geometry?

2. How is geogebra integrated into geometry's teaching and learning process?

3. What is the students' engagement, motivation, and performance levels after the geogebra integration?

4. Is there a significant change in the student's engagement, motivation, and performance after integrating the tool?

5. Is there a significant relationship between the student's performance and classroom engagement and motivation?

6. What are the students' experiences learning geometry using geogebra?

4   Methodology

The study employed a mixed method research to assess the cognitive and non-cognitive effects of incorporating geogebra into geometry instruction. The various questionnaires were used to collect both qualitative and quantitative data. The qualitative data was gathered through student feedback on their experiences with geogebra. In contrast, the quantitative data was derived from the students' pretest and posttest scores regarding engagement, motivation, and performance. One group of pretest-posttest pre-experimental research design was employed to complete the investigation. The research was conducted at one of Cebu province's higher education institutions, specifically the College of Teacher Education. College of Teacher Education students pursuing a BSED major in mathematics and enrolled in plane and solid geometry for the school year 2022-2023 were the research respondents. The actual respondents were determined without using a random selection process. The researchers used purposive sampling technique since the BSED mathematics course in the university could only have one section per subject, the researcher purposefully chose the students enrolled in plane and solid geometry to be the respondents.

In this study, an adapted questionnaire had been used to assess the level of engagement and motivation. The level of engagement of Wang et al. [28] was classified into four categories: cognitive, behavioral, emotional, and social. These factors were measured using a five-point Likert scale, with responses ranging from highly engaged to engaged, neutral, not engaged, and highly not engaged. The Cronbach's alpha of .93 for the overall level of engagement with 33 items can be interpreted as an excellent reliability index. Each of the four factors had good to very good reliability indices ranging from .74 to .89. The instrument was also subjected to predictive validity tests, which revealed that it was significant ($p < 001$). The level of motivation of Fiorella et al. [5] was classified into five categories: intrinsic value, self-regulation, self-efficacy, utility value, and test anxiety. These variables will also be measured using a five-point Likert scale, such as always, usually, occasionally, rarely, and never. The finalized Mathematics Motivation Questionnaire (MMQ) with 19 items and an overall Cronbach's alpha of .85 demonstrated a very good reliability index. Cronbach's alphas for each factor ranged from .73 to .89, indicating good to very good reliability indices. The MMQ was also subjected to and passed the content and internal structure validity tests.

A researcher-created instrument was used to assess the students' test performance. The face validity of the questionnaire was assessed and evaluated by the two (2) experts in mathematics education. The pilot testing was also carried out with twenty (20) recorded third- and fourth-year mathematics major students from the same university where this study was carried out to assess the construct validity. Based on the item analysis results, five items were recorded and suggested for revision, while twenty items were recorded as retained. The revision was made so that the test items could still be used for collecting data. The reliability index was calculated using the split-half method and the Spearman Brown formula by the researcher. The reliability index of .80 was interpreted as a very good reliability index based on the results. The instrument that had been adapted and created by the researcher were used before and after the intervention. The qualitative questionnaire focusing on the two open ended questions (a) What do you like most about the integration of geogebra in the subject? and (b) What do you like least about the integration of geogebra in the subject? The questionnaire was reviewed by five (5) panel members (internal and external) who are experts in education and research during the proposal of the study, and it was agreed that it measures what it intends to measure in the study.

The numerical data collected were analyzed using statistical scales, such as computing the mean, standard deviation, and percentage; and conducting non-parametric tests such as Wilcoxon-signed ranked test and Spearman rank-order correlation to evaluate the changes in engagement,

motivation, and performance. Due to the ordinal nature of the data and the small number of respondents, a non-parametric test had been used to assess the significant change in students' engagement, motivation, and performance following the scale's implementation. The same test was used to determine whether there was a significant relationship between student performance and classroom engagement and motivation. Finally, a thematic analysis was also performed to learn about the students' experiences with geogebra. The researcher carefully evaluated the data to uncover recurring themes - subjects, concepts, and meaning patterns. The researcher also followed Jack Caulfield's six-step thematic analysis process. This includes familiarization, coding, generating themes, reviewing themes, defining and naming themes, and writing up [2].

The study adhered to several ethical considerations. First, there was no conflict of interest as the objective was purely for educational development and professional growth. Second, privacy and confidentiality were maintained by not disclosing any identifying information of the participants. Third, informed consent was obtained from the participants, who were fully informed of the study's purpose and procedures. No risks were involved as the data collection occurred in face-to-face classes with strict adherence to social distancing. Fourth, the recruitment process followed established inclusion criteria, and the study findings may benefit the participants and future students. Lastly, as a token of appreciation, each participant received a gift from the researcher.

5   Results and Discussions

The data from students' mathematics engagement, mathematics motivation, and test performance before and after geogebra integration were presented in this paper chapter. This section also went over the cognitive and non-cognitive effects of geogebra integration and the student's experiences with the software in plane and solid geometry classes.

5.1   Students' pre-experiment pretest on their level of mathematics engagement, motivation, and test performance

Tables 1, 2, and 3 presented and discussed the students' pre-experiment pretest on their level of mathematics engagement, mathematics motivation, and test performance.

Table 1: The students' levels of mathematics engagement before the integration of geogebra as a tool in learning geometry.

Variables	n	M	SD	Verbal interpretation
Cognitive engagement	11	3.55	.72	Engaged
Behavioral engagement	11	3.74	.59	Engaged
Emotional engagement	11	3.30	1.04	Neutral
Social engagement	11	3.34	.85	Neutral
Totality	11	3.48	.75	Engaged

Note: 1.00 - 1.79 – Highly not engaged; 1.80 - 2.59 – Not engaged; 2.60 - 3.39 – Neutral; 3.40 - 4.19 – Engaged; 4.20 - 5.00 – Highly engaged.

Table 1 indicated that, on average, the students had an engaged level of mathematics in terms of cognitive and behavioral engagement with ($M = 3.55$, $SD = .72$) and ($M = 3.74$, $SD = .59$) respectively. The result suggested that the students actively think and participate in mathematics-

related activities, which was a positive sign for their learning and academic progress. However, the standard deviations in these components indicated that there was still some variability in the level of engagement among the students, with some being highly engaged and others needing to be more engaged. On the other hand, the students were still neutral in emotional and social engagement with ($M = 3.30$, $SD = 1.04$) and ($M = 3.34$, $SD = .85$), respectively. This suggested that the students were not highly engaged emotionally or socially in their mathematics activities, which could impact their motivation and interest in the subject. The standard deviations suggested that some students were more emotionally and socially engaged than others.

Overall, the level of mathematics engagement was still at an engaged level with ($M = 3.48$, $SD = .75$). This meant that, on average, the students were reasonably engaged in mathematics. However, the variability in engagement across the different components suggested that there was still room for improvement. With these, mathematics major students already possessed an engagement in mathematics subject. The varying responses of students to this level could be attributed to their previous experiences with mathematics.

This analysis implied that teachers and educators should still focus on increasing emotional and social engagement in their mathematics instruction. This could be achieved by making mathematics activities more interactive and collaborative, encouraging students to work together, and creating a positive and supportive classroom environment. By doing so, students may become more engaged in mathematics, leading to improve academic performance and success. In connection with these, geogebra was still strongly encouraged to improve mathematical learning since it transformed mathematics study into something enjoyable and engaging [25].

Table 2: The students' mathematics motivation levels before the integration of geogebra as a tool in learning geometry.

Variables	n	M	SD	Verbal interpretation
Intrinsic value	11	4.54	.45	Always
Self-regulation	11	3.91	.89	Usually
Self-efficacy	11	3.77	1.04	Neutral
Utility value	11	4.59	.63	Always
Test anxiety	11	3.73	.75	Usually
Totality	11	4.11	.51	Usually

Note: 1.00 - 1.79 – Never; 1.80 - 2.59 – Rarely; 2.60 - 3.39 – Sometimes; 3.40 - 4.19 – Usually; 4.20 - 5.00 – Always.

Table 2 indicated that the students always had intrinsic and utility value towards the task, as indicated by their mean scores and standard deviation of ($M = 4.54$, $SD = .45$) and ($M = 4.59$, $SD = .63$) respectively. In intrinsic value, all items such as "I enjoy learning math", "I find learning math interesting", and "I like math that challenges me" were recorded as "always" as their level of motivation in learning mathematics. The same results were recorded for all the items in the utility value, such as "I think about how the math I learn will be helpful to me", "I think about how I will use the math I learn", "I think about how learning math can help me get good", and "I think about how learning math can help my career".

Additionally, the students usually had a level with mean and standard deviation of ($M = 3.91$, $SD = .89$) for self-regulation and ($M = 3.77$, $SD = .82$) for self-efficacy. In self-regulation, two items were recorded as "always" level such as "I put enough effort into learning math" and "If I am having trouble learning math, I try to figure out why", one for usually: "I use strategies that ensure I learn math well", and one for sometimes: "I prepare well for math tests and quizzes".

In self-efficacy, all items were recorded as the "usual" level of mathematics motivation, such as "I am confident I will do well on math assignments and projects", "I am confident I will do well on math tests", "I believe I can master the knowledge and skills in the math course", and "I believe I can earn a grade of "A" in the math course". This meant they regulated their behavior and had moderate confidence in their abilities.

Finally, the students had a mean and standard deviation of ($M = 3.73$, $SD = .75$) for test anxiety, indicating that they usually felt anxious about the task. Items such as "I become anxious when it is time to take a math test", "I am nervous about how I will do on the math tests", and "I worry about failing math tests" were recorded to be usual. One item was recorded as "sometimes" for "I am concerned that the other students are better in math". The mean and standard deviation of ($M = 4.11$, $SD = .51$), meant that the overall level of mathematics motivation was at a "usual" level. Thus, the students positively viewed the task. This implied that before the geogebra integration, the students felt optimistic about the task and were confident in their ability to complete it. This may result in better learning outcomes because students were more likely to be motivated and engaged in the task. Furthermore, the "usual" level of anxiety suggested that the students were under some pressure, which could help them stay focused and motivated to complete the task.

In line with this study on the effects of geogebra integration, Mendoza and Mendoza [17] suggested the used of software as a motivating resource for the construction of meaningful learning, and Fuqoha et al. [6] asserted that high learning motivation, understanding of mathematics materials supported by the used of good learning media was also required. Finally, Condori et al. [19] suggested that the used of software generated great interest and motivation in pedagogical activities, and with the used of geogebra, a level of practical understanding was acquired in the development of geometry.

Table 3: The students' levels of test performance before the integration of geogebra as a tool in learning geometry.

Competency	Percentage (%)	Verbal interpretation
1. Lines, angles, and triangles	9	Beginning
2. Basic angle theorems	21	Beginning
3. Congruent triangles	30	Beginning
4. Parallel lines, distances, and angle sums	18	Beginning
5. Parallelograms, trapezoids, medians and midpoints	15	Beginning
6. Circle	7	Beginning
7. Areas	4	Beginning
Totality	13	Beginning

Note: Beginning – (74% and below), Developing – (75 - 79%), Approaching proficiency – (80 - 84%), Proficient – (85 - 89%), and Advanced – (90% and above). Competency 1 – four items, Competency 2 – three items, Competency 3 – three items, Competency 4 – three items, Competency 5 – three items, Competency 6 – four items, Competency 7 – five items, Totality – 25 items.

Table 3 indicated that the student's pretest performance in all competency areas fell on a "beginning" level, with a percentage of scores below 74 %. The third competency had the highest score, while the seventh competency had the lowest. The third competency, which was congruent triangles, indicated that students had a better background in this area compared to other competencies such as lines, angles, triangles, fundamental angle theorem, parallel lines, distances, angle sums, parallelograms, trapezoids, medians, midpoints, circle, and areas. This data suggested that

students had some prior knowledge of plane and solid geometry before the experiment, as they performed better in congruent triangles, a concept typically taught earlier in geometry courses. Furthermore, the fact that all students performed similarly on the pretest suggested that the sample was representative of the population, an important consideration when conducting research.

The analysis implied that students' prior knowledge of geometry can impact their performance in the experiment. Consider students' varying levels of competency when designing instructional materials or interventions to improve their performance in geometry. In line with this study on geogebra integration, Condori et al. [19] suggested that the aid of geogebra in learning geometry generated great interest and motivation, leading to effective performance in geometry. In addition, Fuqoha et al. [6] determined that strong learning motivation and understanding of mathematical topics complemented by a suitable educational medium are essential.

The following section responded to the second sub-problem and discussed how geogebra was being integrated into the geometry teaching and learning process.

5.2   The integration of geogebra in teaching and learning of geometry

In the classroom, the researcher's teaching focused on finding new and innovative ways to engage students in the learning process. The researcher sought ways to provide students with an enhanced learning experience and had recently begun incorporating the use of geogebra in geometry teaching and learning. Geogebra was known as a powerful dynamic mathematics software that allowed students to explore and manipulate geometric figures in a visually appealing and intuitive way.

Geogebra was used in classrooms to help students develop a deeper understanding of geometry by providing the students with hands-on experience. The software allowed students to investigate points, lines, angles, symmetry, and area. Students could better understand the relationships between various objects by manipulating the geometric objects in geogebra. For example, move points around to investigate the properties of lines, angles, and other shapes. The students could also used the software to create figures from scratch and investigate the properties and principles of those figures. Geogebra could be used to help students develop problem-solving skills as well as help them understand geometry. Students could use the software to create their problems and investigate potential solutions.

The researcher had also created a lesson plan using Madeline Hunter's model for integrating geogebra into geometry's teaching and learning process. The set of topics were identified using the textbook guide of Rich and Thomas [23]. The lesson plan included activities that allowed students to manipulate geometric objects using software, explore some properties and principles of different shapes, create their projects, and develop problem-solving skills. The lesson plans guided the researcher during the study's implementation.

5.3   Students' pre-experiment post-test on their level of mathematics engagement, motivation, and test performance

The third part of the discussion was Tables 4, 5, and 6, which presented and discussed the students' posttest levels of mathematics engagement, mathematics motivation, and test performance following the geogebra integration. The experiment lasted for two and a half months, which was

considered within the standard duration for experimental research.

Table 4: The students' mathematics engagement levels after the geogebra integration as a tool in learning geometry.

Variables	n	M	SD	Verbal interpretation
Cognitive engagement	11	4.24	.53	Highly engaged
Behavioral engagement	11	4.08	.41	Engaged
Emotional engagement	11	4.44	.52	Highly engaged
Social engagement	11	4.51	.44	Highly engaged
Totality	11	4.32	.40	Highly engaged

Note: 1.00 - 1.79 – Highly not engaged; 1.80 - 2.59 – Not engaged; 2.60 - 3.39 – Neutral; 3.40 - 4.19 – Engaged; 4.20 - 5.00 – Highly engaged.

Table 4 indicated that, on average, the students were "highly engaged" in mathematics in terms of cognitive, emotional, and social engagement with ($M = 4.24$, $SD = .53$), ($M = 4.44$, $SD = .52$), and ($M = 4.51$, $SD = .44$) respectively. In addition, the students were "engaged" in behavioral engagement with ($M = 4.08$, $SD = .41$). This data had several implications. Firstly, the geogebra integration could increase mathematics engagement. The increased in engagement across all aspects showed that the intervention successfully improved students' understanding of mathematics and their emotional and social connection to the subject. Secondly, the data suggested that the students were receptived to the intervention and willing to engage in mathematics at a higher level. This was important as it indicated that students could be motivated to engage with mathematics when given the proper support and guidance.

Overall, the data showed an increased in mathematics engagement level compared to their pretest results. The level of mathematics engagement indicated a "highly engaged" level with ($M = 4.32$, $SD = .40$). This suggested that the students were motivated and interested in the task and were able to engage with the material and with the help of geogebra on a cognitive, emotional, behavioral, and social level. Based on the findings of the students' experiences of this study, it revealed that students enjoyed using geogebra's slider feature. This feature allowed students to interact with various mathematical concepts and investigated how changes in input parameters could affect results.

This further implied that the respondents felt connected to their peers and were involved in activities that led to meaningful connections and relationships. Furthermore, the respondents might have felt connected to themselves, allowing them to fully engage in activities that led to meaningful reflection and mathematical growth. Moreover, this could imply that the used of geogebra in teaching geometry successfully engages students and provides them with a learning environment. Thus, high levels of engagement resulted in improved learning outcomes because students were more likely to remember and apply the material learned in the task.

The findings of this study on the used of geogebra in geometry teaching supported previous studies; according to the study, employing geogebra boosted student engagement and performance [26] and improved mathematical learning by making mathematics more enjoyable and fascinating [25]. In addition, incorporating various technologies into 21st-century teaching and learning increased interaction between teachers and students [1]. Furthermore, integrating geogebra software into the classroom demonstrated to be an effective tool for improving student achievement and engagement [8]. As a result, the findings of this study indicated that using geogebra in geometry could benefit students by providing an interactive and engaging learning experience.

Table 5: The students' mathematics motivation after the geogebra integration as a tool in learning geometry.

Variables	n	M	SD	Verbal interpretation
Intrinsic value	11	4.39	.66	Always
Self-regulation	11	4.25	.80	Always
Self-efficacy	11	3.93	1.01	Usually
Utility value	11	4.45	.66	Always
Test anxiety	11	3.50	.96	Usually
Totality	11	4.11	.66	Usually

Note: 1.00 - 1.79 – Never; 1.80 - 2.59 – Rarely; 2.60 - 3.39 – Sometimes; 3.40 - 4.19 – Usually; 4.20 - 5.00 – Always.

Table 5 showed a slight decreased in intrinsic and utility value, but still, and the data indicated that the students had an "always" level of intrinsic and utility value towards the task with ($M = 4.39$, $SD = .66$) and ($M = 4.45$, $SD = .66$) respectively. All intrinsic and utility value items were leveled as "always" in their mathematics motivation. Despite a slight decreased in these values, the data showed that most of the students responded with an "always" rating, which suggested that the students were still interested in mathematics. This could be attributed to the potential for personal and professional development that mathematics offers and the strong appeal of the subject. The decreased in their level in the component was the result of the number of challenges of the students in using geogebra. Challenges could range from process complexity to learning difficulties to technology issues.

Additionally, the students had a mean score and standard deviation of ($M = 4.25$, $SD = .80$) for self-regulation and ($M = 3.93$, $SD = 1.01$) for self-efficacy, which showed an increased in their level compared to their pretest. In the students' self-regulation, three items were recorded as "always" such as "I put enough effort into learning math", "If I am having trouble learning math, I try to figure out why", and "I use strategies that ensure I learn math well". At the same time, "I prepare well for math tests and quizzes" was leveled as "usual". In addition, in the students' self-efficacy, all items were recorded as "usually" as their level of mathematics motivation. The data indicated that they regulated their behavior and had more confidence in their abilities.

Furthermore, the students had a mean and standard deviations of ($M = 3.50$, $SD = .96$) for test anxiety, which decreases compared to their pretest level. Items such as "I become anxious when it is time to take a math test" and "I am concerned that the other students are better in math" were leveled as "sometimes", while items such as "I am nervous about how I will do on the math tests" and "I worry about failing math tests" were recorded as "usually" as their level of mathematics motivation. The data indicated that they were less feeling anxious about the task. Finally, the mean and standard deviation of the data ($M = 4.11$, $SD = .66$) indicated that the overall level of mathematics motivation was at the "usual" level. Thus, the students still positively viewed the task.

The findings of this research supported the previous literature. According to Dunn and Zimmer [4], intrinsic motivation was a significant aspect of encouraging engagement in learning, and students with a high level of intrinsic motivation were more likely to stay interested in a subject. Self-regulation and self-efficacy were essential components in enhancing task engagement, as they led to improve engagement in learning mathematics. Moreover, test anxiety negatively correlated with engagement and performance [16]. Lastly, according to Condori et al. [19], the used of software generated great interest and motivation in pedagogical activities, and with the used of geogebra, a level of practical understanding was acquired in the development of geometry.

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As a result, the findings of this study were consistent with previous research on motivation and engagement in learning.

Table 6: The students' test performance after geogebra integration as a tool in learning geometry.

Competency	Percentage (%)	Verbal interpretation
1. Lines, angles, and triangles	91	Advanced
2. Basic angle theorems	76	Developing
3. Congruent triangles	48	Beginning
4. Parallel lines, distances, and angle sums	76	Developing
5. Parallelograms, trapezoids, medians and midpoints	52	Beginning
6. Circle	73	Beginning
7. Areas	29	Beginning
Totality	62	Beginning

Note: Beginning – (74% and below), Developing – (75 - 79%), Approaching Proficiency – (80 - 84%), Proficient – (85 - 89%), and Advanced – (90% and above). Competency 1 – four items, Competency 2 – three items, Competency 3 – three items, Competency 4 – three items, Competency 5 – three items, Competency 6 – four items, Competency 7 – five items, Totality – 25 items.

Table 6 showed that the students had improved their posttest performance compared to their pretest in all competencies. This was a positive sign as it indicated that the students had learned and retained some of the knowledge they have been taught during study. The data indicated that the students had excelled in the first competency, "lines, angles, and triangles" with 91% achieving an "advanced" level. This suggested that the teaching methods used for this competency were effective and should be considered in other competencies. However, the students had only achieved a "developing" level with 76% in the second and fourth competencies, "basic angle theorems" and "parallel lines, distances, and angle sums". This suggested that the teaching methods used for these competencies could revisit and revise to improve students' understanding of these topics.

The remaining competencies, including "congruent triangles", "parallelograms, trapezoids, medians, and midpoints", "circle", and "areas" were still at a "beginning" level. However, the data showed that there was an increased in the student's performance in these competencies compared to their pretest. This indicated that the teaching methods used had been effective in these areas, but further improvement was necessary to bring the students up to an "advanced" level. This supported the students' experiences in using geogebra. Incorporating geogebra into geometry instruction could be a beneficial and valuable tool for students and teachers, providing students with a more interactive and engaging experience.

In addition, the data was analyzed using a standard score. According to Stanine, 27% of the students were above average, 46% were average, and 27% were below average. This implied that geogebra could assist students in understanding concepts and problem-solving in geometry, as well as maintain and increase their level of engagement, motivation, and test performance. However, geogebra cannot guarantee outstanding performance in mathematics. The findings of this research supported the previous studies. According to Condori et al. [19], that the used of software generated a high level of interest and motivation in pedagogical activities, and that geogebra provided a level of effective knowledge in the development of geometry. In addition, Ngwabe and Felix [18] claimed that students improved their grasp of mathematics through geogebra engagement. However, Sabornido et al. [24] discovered that the main problems and limitations in integrating software implementation included students who could be more engaged, which may

be detrimental to task completion and overall student performance.

The data suggested that the geogebra integration had been effective, but there was room for improvement in certain areas. The implication was that the teachers should revisited and revised some methods for the competencies in which the students performed better. This helped to improve the student's understanding and performance in these areas and ultimately led to a more well-rounded education.

5.4 The change in students' mathematics engagement, motivation, and performance following the geogebra integration

Table 7: The change in students' mathematics engagement following the integration of the tool.

| Variable | Pretest | | Posttest | | | Wilcoxon signed rank |
	M	SD	M	SD	Z	test probability
Cognitive engagement	3.55	.72	4.24	.53	-2.00	.045
Behavioral engagement	3.74	.59	4.08	.41	-1.53	.126
Emotional engagement	3.30	1.04	4.44	.52	-2.25	.024
Social engagement	3.34	.85	4.51	.44	-2.50	.012
Totality	3.48	.75	4.32	.40	-2.31	.021

Note: n = 11.

Table 7 showed that there were significant changes in cognitive engagement with ($p < .05$), emotional engagement with ($p < .05$), and social engagement with ($p < .05$) following the integration of geogebra. This meant that geogebra maintained and increased their level in these aspects, which could benefit learning and overall academic performance. However, there was no significant change in behavioral engagement with ($p > .05$), which meant that there was only a slight increased in their behavioral level after integrating the geogebra, leading to insignificant results. Descriptive statistics showed an "engaged" level on both pretest and posttest.

Overall, the analysis revealed a statistically significant change in the level of mathematics engagement following the integration of geogebra into the curriculum with ($p < .05$). This indicated that the integration of geogebra effectively increased student engagement in mathematics. This was an important finding, as student engagement was a critical factor in academic success, and technology tools like geogebra could effectively improved student engagement in the classroom. This supported the students' experiences during the intervention that they enjoy using geogebra in the teaching and learning process.

As a result of the findings, respondents reported feeling connected to their peers and engaging in activities that led to meaningful connections and relationships. Furthermore, the respondents felt connected to themselves, allowing them to fully engage in activities that led to meaningful reflection and mathematical growth. The findings of the study supported the previous research that the used of geogebra helped to shift mathematics learning to be entertaining and exciting [25], and that geogebra implementation was indeed capable of enhancing students' engagement and achievement ([26]; [8]), and Ngwabe and Felix [18] confirmed that by using geogebra, most students increased their comprehension, visualization, and interpretation of the offered mathematics topics.

Table 8: The change in students' mathematics motivation following the integration of the tool.

Variable	Pretest		Posttest			Wilcoxon signed rank
	M	SD	M	SD	Z	test probability
Intrinsic value	4.54	.45	4.39	.66	-0.68	.495
Self-regulation	3.91	.89	4.25	.80	-1.18	.238
Self-efficacy	3.77	.82	3.93	1.01	-0.42	.677
Utility value	4.59	.63	4.45	.66	-1.00	.269
Test anxiety	3.73	.75	3.50	.96	-1.13	.259
Totality	4.11	.51	4.11	.66	-0.30	.767

Note: n = 11.

Table 8 showed that there were no significant changes in the intrinsic value with ($p > .05$), self-regulation with ($p > .05$), self-efficacy with ($p > .05$), utility value with ($p > .05$), and test anxiety with ($p > .05$) following the integration of geogebra. This meant only slight increased and decreased in their mathematics motivation level after integrating the tool. Overall, the research demonstrated a statistically insignificant change in student mathematics motivation following the incorporation of geogebra into the curriculum ($p > .05$). This aligned with their experiences during the intervention on navigating educational technology challenges, including process complexity, learning difficulties, and technology issues.

This implied that the student's motivation's slight decreased in intrinsic value, utility value, test anxiety, and an increased in self-regulation and self-efficacy following geogebra integration were not significant. Another factor to consider in these findings was that high achiever students had a high level of mathematics motivation, whereas average students had a low level of mathematics motivation. This supported the previous research that underachiever learners were discovered to have poor motivation levels in learning mathematics [22]. Students had more control of their mathematics motivation, similar to teachers when highly motivated to do the task they perform well. Petancio et al. [21] found that teaching interns had more control over how they learned, what they learned, their emotions, motivations, and attitudes toward learning, which were all parts of metacognitive self-regulation, then their teaching performance in math increases.

The findings of the study suggested that integrating geogebra as a teaching tool could positively impacted students' engagement and motivation in learning mathematics. Mathematics major students were already engaged and motivated to learn mathematics before the experiment. However, the study revealed a slight increased and decreased in their motivation before and after the tool's integration, providing a clearer picture of some changes in this group of students. Geogebra was a teaching tool that maintained and enhanced students' engagement and motivation in learning mathematics concepts. According to Fuqoha et al. [6], using good learning media encouraged high learning motivation among students.

Therefore, the study provided evidence of the benefits of integrating technology in the classroom to support students' learning and achievement of academic goals. Teachers could create more engaging and interactive learning experiences using tools like geogebra, promoting more profound understanding and higher student motivation.

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Table 9: The change in students' test performance following the integration of the tool.

Variable	Pretest		Posttest			Wilcoxon signed rank
	M	SD	M	SD	Z	test probability
Lines, angles, and triangles	.36	.67	3.64	.67	-2.98	.003
Basic angle theorems	.64	.67	2.27	1.27	-2.44	.015
Congruent triangles	.91	.83	1.45	1.37	-1.67	.096
Parallel lines, distances, and angle sums	.55	.82	2.27	.90	-2.84	.005
Parallelograms, trapezoids, medians, and midpoints	.45	.69	1.55	1.13	-2.36	.018
Circle	.27	.65	2.91	.94	-2.96	.003
Areas	.18	.40	1.45	1.37	-2.35	.019
Totality	3.36	3.11	15.55	6.20	-2.94	.003

Note: n = 11.

Table 9 showed that there were significant changes in the first competency (lines, angles, and triangles with ($p < .05$)); second competency (basic angle theorems with ($p < .05$)); fourth competency (parallel lines, distances, and angle sums with ($p < .05$)); fifth competency (parallelograms, trapezoids, medians, and midpoints with ($p < .05$)); sixth competency (circle with ($p < .05$)); and seventh competency (areas with ($p < .05$)) following the integration of geogebra. This indicated that geogebra could effectively improved students' understanding and application of geometry concepts.

However, the data showed a non-significant change in the third competency (congruent triangles, $p > .05$). This could have been due to various factors, such as the teaching approach or the students' prior knowledge. This finding aligned with navigating educational technology challenges based on the student's experiences, specifically on the technology issues, since their task on this competency was based on the online exploration of the congruent angles based on the predesigned applet. It indicated that students were frustrated when their internet connection was poor. The insignificant results of this competency supported the previous research indicated that students who used the mathematics software program were highly engaged. However, when comparing the pretest and posttest scores, the results were statistically non-significant to draw any conclusions on the impact on learners' achievement [10].

The analysis revealed that there was a statistically significant change in the overall student test performance after the integration of geogebra into the curriculum ($p < .05$). This meant that the integration of geogebra into the curriculum had a positive impact on student test performance and had a significant effect on the students' learning. In addition, the high level of mathematics engagement and motivation of the students had helped towards their academic performance. This suggested that technology could be a valuable resource for educators in enhancing student learning and achievement in mathematics. The results of this study might have encouraged other educators to explore the use of geogebra or other technology tools in their teaching.

The findings of the study supported the previous research that technology aided in the delivery of learning materials and the improvement of academic learning goals [3], and the adaptation and used of numerous digital technologies in 21st-century teaching and learning had resulted in significant changes in instructional delivery and outcomes [1]. Finally, Ngwabe and Felix [18]

argued that students' grasp of mathematics improved through engagement with geogebra.

Table 10: The relationship between students' performance and their classroom engagement and motivation.

Variable	n	M	SD	1	2	3
1. Level of mathematics engagement	11	4.32	.40	_		
2. Level of mathematics motivation	11	4.11	.66	$.81^{**}$	_	
3. Level of test performance	11	15.55	6.20	.29	.48	_

Note**: Correlation is significant at the 0.01 level (2-tailed).

Table 10 revealed that students' mathematics engagement had a significant positive relationship with mathematics motivation ($r = .81$, $p < .01$). The data showed a very strong correlation between students' level of engagement and mathematics motivation. The result suggested that students who were more engaged in the classroom had higher levels of mathematics motivation. This indicated that classroom engagement was an essential factor in student motivation and should be considered when designing instruction and assessing student motivation in mathematics. The result supported the previous study that geogebra gave students higher motivation and made learning joyful [15]. According to the findings, mathematics engagement was essential to mathematics motivation. The findings also supported the students' experiences during the intervention using geogebra. The students demonstrated interest in learning through hands-on engagement with geogebra. This study also revealed that students enjoyed using geogebra in the learning process.

However, the analysis revealed that the students'mathematics engagement had a nonsignificant weak correlation with their test performance ($r = .29$, $p > .05$). This indicated that while engagement took an important role in motivation, mathematics engagement only took a weak relationship to improve academic performance. In line with the students' experiences, geogebra integration posed several challenges. As previously stated, challenges ranged from process complexity to learning difficulties to technology issues. This finding supported the previous research that students' personal and interpersonal values do not significantly affected their performance in mathematics [12]. Thus, some students increased their mathematics engagement after the intervention but needed help to excel on the test. At the same time, some of the students increased their level of mathematics engagement and were able to excel on the test. This analysis resulted in a weak correlation between these two variables.

Finally, the analysis revealed that students' mathematics motivation had a statistically nonsignificant moderate positive relationship with mathematics test performance ($r = .48$, $p > .05$). This indicated that while there might have been some correlation between student mathematics motivation and test performance, the strength of the relationship was not statistically significant. This implied that while motivation might have been necessary for academic performance, other factors, such as student ability or test-taking skills, might have significantly influenced test scores. Therefore, the geogebra integration should have aimed to create a learning environment that fostered motivation and academic skills to improve students' overall performance in mathematics.

The next part of the discussion focused on the students' experiences in learning geometry using geogebra. The students' experiences were explored qualitatively to identify what they liked most and least in geogebra integration. The researcher followed Jack Caulfield's six-step thematic analysis process, which included familiarization, coding, generating themes, reviewing themes, defining and naming themes, and writing up. The results of the research revealed two major themes. First, enhancing geometry skills through hands-on engagement with geogebra and second, navigating educational technology challenges.

5.5 Students experiences in learning geometry using geogebra

The following themes emerged based on the analysis of the students' narratives in the geogebra integration in teaching and learning geometry. These themes shed light on how geogebra was integrated into geometry instruction and affects student learning. This part of the study focused on the themes that emerged from the student's feedback and discussed how they related to geogebra teaching and learning.

Theme 1: Enhancing geometry skills through hands-on engagement with geogebra

Geometry as a fundamental subject that was essential for students to understand. Nowadays, integrating geogebra into the teaching of geometry was increasingly popular. This was due to the convenience and engaging hands-on learning opportunities it provided students, which could assist them in improving their geometry skills. Recent studies revealed that students visualized geometric figures well, indicating success in integrating geogebra into geometry. They could improve their understanding of learning mathematical concepts using geogebra and demonstrated interest in learning through hands-on engagement with the tool. Additionally, students enjoy using geogebra's slider feature, which allowed them to interact with various mathematical concepts and investigate how changes in input parameters could affect results.

Hands-on learning benefited students by allowing them to understand better the concepts they were learning. Therefore, geogebra's slider feature could be helpful for students as they explored geometry. During interventions, hands-on engagement with geogebra was a valuable learning tool for students, as evidenced by their insightful responses about the experience.

"I like geogebra because we can see the exact measures of angles, areas, etc. I can easily understand the principles of polygons, which can be proven using geogebra. I can create shapes, sliders, and more using geogebra, which helps me understand geometry concepts deeper", "Geogebra helped me understand geometry more precisely. It also contained many mathematical concepts that I had only recently discovered. It also allows me to create some amazing animations", and "I like the application on how it is convenient for the students. It makes graphing easier and budget-friendly in learning geometry. I cannot pick what I most like because the overall application is considered fabulous. I love all the tools, especially the slider. I am very thankful that I learned about this application. It serves as a tool for me, especially on becoming the next educator for the next generation".

These findings highlighted the potential benefits of integrating geogebra into geometry instruction. The study demonstrated that using geogebra enhances students' engagement and motivation and promotes their conceptual understanding of mathematics [22]. Students were able explore and manipulate geometric figures using geogebra, gaining a better understanding of their properties and relationships. This hands-on engagement promoted a more active and collaborative learning environment in which students could work together to solve complex problems and develop their critical thinking skills.

Furthermore, using geogebra provided teachers with valuable insights into their students' learning progress, as it allowed them to track their students' interactions with the software and monitor their understanding of mathematical concepts. This enabled teachers to tailor their instruction to meet the individual needs of their students and provide them with targeted support. Overall, the results of this study indicated that incorporating geogebra into geometry instruction could effectively improve students' mathematical learning experiences and promote their overall academic success. Geogebra could help students improve their motivation, engagement, and test performance in mathematics by providing a more interactive and engaging learning environment.

Theme 2: Navigating educational technology challenges

The students encountered a number of difficulties while using geogebra. Process complexity, learning difficulties, and technology issues were among the challenges faced by the students. Process complexity suggested students had difficulty understanding and carrying out specific tasks, such as creating a slider or encoding commands to add animations. Learning difficulties indicated that students need helped understanding the application and its features. Finally, technology issues indicated students were frustrated when their internet connection was poor.

The study provided valuable insights for future researchers on the challenges students may encounter while utilizing geogebra integration in teaching geometry. Below were a few examples of the feedback received from students in the study.

"In the whole application of geogebra, from the start to the current discussion, I like all the steps in creating such polygons, etc. I liked it the least when it had different steps in following the exact positions. It has a lot to memorize, and it was confusing sometimes", "A little complicated, you need to familiarize the settings and also to make it easier you need to memorize the pattern", "Encoding commands to add animations. I find it difficult, and I need a guide to add animations successfully", and "I just do not like it when the internet connection is poor".

This implied that using geogebra integration posed several challenges to students. As previously stated, challenges ranged from process complexity to learning difficulties to technology issues. Despite these obstacles, students were lured to the self-learning idea and the slider feature during their educational experiences [22]. To minimize or eliminate these challenges, it was necessary to investigate ways to improve the user experience when integrating geogebra.

One possible solution was to provide students with clear and concise instructions for using geogebra through video tutorials or step-by-step guides. This made it easier for students to navigate the software and reduced frustration. Another strategy was to scaffold the learning process by separating complex concepts into smaller, more manageable chunks. This allowed students to build their understanding gradually and reduced the likelihood of being overwhelmed. Thus, it was critical to ensure that the technology used was reliable and up to date. This could have included providing students with high-speed internet access or ensuring they had the necessary hardware and software to run geogebra smoothly. By addressing these challenges and improving the user experience, educators could help students make the most of geogebra and support their mathematical learning.

6   Conclusions

It is therefore concluded that the investigation on the cognitive and non-cognitive effects of using geogebra for geometry learning among BSED mathematics students provided valuable insights. Integrating geogebra significantly improved student mathematics engagement and test performance. This is crucial because engagement fosters learning and academic success. Geogebra also facilitated a more engaging and dynamic exploration of geometric concepts, potentially leading to deeper understanding. However, the study did not find a significant impact on student motivation. This suggests that while geogebra enhances other aspects of learning, it may not directly address motivation. Further research could explore how technology can be used more innovatively to promote both motivation and engagement. The identified student challenges during geogebra implementation highlight the importance of providing appropriate training and sup-

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port. This ensures students can effectively leverage technology in their learning. Finally, this study has significant implications for university curriculum developers and instructional strategists. The findings emphasize the need for designing and implementing the enhancement of technology-aided instruction that addresses student challenges while promoting mathematics engagement, motivation, and performance. By strategically integrating geogebra, educators can equip future mathematics teachers with stronger geometry skills and foster a more engaging learning environment.

7   Recommendations

 Drawing from the results and findings presented in this study, it is recommended that:

1. Educators consider integrating geogebra into their mathematics teaching as it can help students understand concepts and problem-solving in geometry, improve their engagement and motivation, and improve their test performance.

2. It is advised that a study be undertaken to assess the effects of geogebra on student engagement toward mathematics, student achievement, and student motivation over a more extended period to investigate the influence of geogebra on students better.

3. It is also suggested that research be conducted to assess the efficacy of incorporating geogebra into other learning contexts.

4. Furthermore, research should be conducted to investigate the implications of various instructional approaches when incorporating geogebra into the curriculum, such as student-centered instruction, virtual learning, and blended learning.

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