

Research paper**Mathematics teachers' attitudes toward the use of GeoGebra in the teaching and learning of mathematics in Ghana: A case study of Dormaa East, West, and Central municipalities**

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ABSTRACT

Mathematics education in Ghana is increasingly integrating digital technologies to strengthen teaching and learning. This study examined mathematics teachers' attitudes toward the use of GeoGebra in Junior and Senior High Schools across the Dormaa East, Dormaa West, and Dormaa Central Municipalities. The sample comprised 108 teachers (60 males and 48 females). Guided by the Technology Acceptance Model and informed by the Theory of Planned Behavior and the TPACK framework, the study explored perceived usefulness and ease of use through three domains: emotional attitudes, instructional experiences, and beliefs about cognitive benefits. Data were collected using a structured questionnaire and analyzed with descriptive statistics, Pearson correlation, and one-way ANOVA. Findings revealed generally positive attitudes toward GeoGebra across all domains, with teachers recognizing its value in improving conceptual understanding, visualization, lesson delivery, problem-solving, and student engagement. Significant correlations were found among the domains, while ANOVA results showed no statistically significant gender differences ($p > .05$). The study concludes that sustained integration requires structured professional development and improved instructional and technical support.

Keywords: GeoGebra, technology integration, instructional experience, cognitive benefits, emotional attitudes

Mathematics is a core discipline that underpins scientific advancement, technological innovation, economic development, and problem-solving in everyday life. In Ghana, mathematics is a compulsory subject from the basic to the tertiary levels, underscoring its central role in national development and human capital formation. Despite its importance, mathematics learning outcomes remain a persistent concern, with many learners experiencing difficulty in understanding abstract concepts and applying mathematical knowledge effectively. These challenges are often associated with continued reliance on traditional, teacher-centered instructional approaches that limit learner engagement and conceptual exploration.

The rapid advancement of Information and Communication Technology (ICT) has created opportunities to transform mathematics teaching and learning. ICT tools facilitate visualization, interaction, and experimentation,

enabling learners to engage more meaningfully with mathematical ideas. Voogt & Pelgrum (2005) conceptualized educational technology as both a medium for instruction and an object of learning, influencing curriculum content, pedagogical practices, and learning objectives. Empirical evidence suggests that effective ICT integration enhances learners' understanding, motivation, and engagement in mathematics classrooms (Lagura, 2022; Mensah et al., 2023; Mijares, 2022; Lotey et al., 2023). Among ICT-based tools developed for mathematics education, GeoGebra has gained widespread recognition. GeoGebra is a dynamic mathematics software that integrates geometry, algebra, calculus, and statistics into a single interactive environment (Hohenwarter, 2008). As a freely available and user-friendly application, it enables learners to visualize and manipulate mathematical objects, thereby supporting conceptual understanding, inquiry-based learning, and creativity (Abramovich, 2013).

Studies conducted across diverse educational contexts indicate that GeoGebra enhances students' academic performance, supports deeper conceptual learning, and increases classroom engagement (Arbain & Shukor, 2015; Chimuka, 2017; Joshi & Singh, 2020; Asare & Atteh, 2022). Although substantial attention has been given to student learning outcomes, teachers remain the primary agents of ICT integration. Their attitudes, beliefs, and instructional experiences significantly influence whether and how digital tools such as GeoGebra are adopted in classroom practice. Understanding teachers' attitudes toward GeoGebra is therefore critical, particularly within contexts such as Ghana, where ICT integration in education is increasingly emphasized but unevenly implemented.

Research gap and statement of the problem

Existing literature strongly supports the pedagogical value of GeoGebra in improving mathematics teaching and learning outcomes. Studies consistently highlight its potential to enhance conceptual understanding, visualization, engagement, and problem-solving skills. At the same time, research examining gender differences in technology use suggests that such differences are neither fixed nor inherent, but rather shaped by contextual, institutional, and pedagogical conditions.

However, within the Ghanaian context, research remains heavily concentrated on student achievement outcomes, with limited attention given to teachers' attitudes toward instructional technologies. This represents a significant gap, as teachers serve as the primary agents of curriculum implementation and instructional innovation. Their emotional responses, instructional experiences, and beliefs about the cognitive value of digital tools directly influence whether such technologies are meaningfully integrated into classroom practice.

Furthermore, inconsistencies in the international literature regarding gender and technology acceptance raise important theoretical questions. While frameworks such as the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), and Technological Pedagogical Content Knowledge (TPACK) offer useful explanations for technology adoption, their applicability in specific educational and cultural contexts—such as Ghana—remains insufficiently tested. The absence of teacher-focused, gender-sensitive research limits the ability to determine whether these models adequately explain technology integration patterns in Ghanaian mathematics classrooms. From a practical standpoint, the lack of empirical evidence on gender-based teacher attitudes may weaken the design of professional development programmes and ICT integration policies. Without a clear understanding of whether gender influences teachers' readiness, confidence, or perceptions of usefulness, interventions risk being either overly generalized or insufficiently targeted.

The present study addresses this gap by systematically examining gender-based differences in Ghanaian mathematics teachers' attitudes toward GeoGebra across emotional, instructional, and cognitive dimensions. By grounding the investigation in TAM, TPB, and TPACK, the study contributes both theoretically and practically to ongoing efforts aimed at strengthening sustainable ICT integration in mathematics education in Ghana.

Purpose of the study

The purpose of this study is to investigate the attitudes of male and female mathematics teachers toward the use of GeoGebra as a tool for mathematics instruction and learning among Junior High School and Senior High School teachers in Ghana. Specifically, the study examines teachers' emotional attitudes, instructional experiences, and cognitive beliefs regarding GeoGebra use, and determines whether gender significantly influences these attitudes.

Research questions

1. What emotional attitudes do mathematics teachers hold toward the use of GeoGebra in mathematics instruction?
2. How do mathematics teachers perceive their instructional experiences with GeoGebra?
3. What beliefs do teachers hold regarding GeoGebra's cognitive benefits for students?

4. Is there a difference between the mean attitudes of male and female mathematics teachers toward the use of GeoGebra in teaching mathematics?

Research hypotheses

- H_0 : There is no significant difference in the mean attitudes of male and female mathematics teachers toward the use of GeoGebra in mathematics instruction and learning.
- H_a : There is a significant difference in the mean attitudes of male and female mathematics teachers toward the use of GeoGebra in mathematics instruction and learning.

LITERATURE REVIEW

A critical thematic synthesis

Empirical studies consistently demonstrate the instructional benefits of GeoGebra in mathematics education. Research indicates that GeoGebra enhances conceptual understanding, promotes active learner engagement, and improves academic performance (Asare & Atteh, 2022; Adesina & Sosanwo 2025; Dogan, 2011; Lamichhane, 2017; Saha et al., 2010). Studies conducted in Ghana similarly report positive teacher perceptions and willingness to adopt GeoGebra in classroom instruction (Mensah et al., 2023).

However, evidence regarding gender differences in attitudes toward educational technology remains inconclusive. Some studies suggest that male teachers exhibit higher confidence and familiarity with digital tools (Marange & Tatira, 2024), while others report no significant gender differences in perceptions of GeoGebra's instructional value (Munyaruhengeri et al., 2025). Comparable inconsistencies are evident in student-focused research, with some studies identifying gender-based differences in performance (Pavethira & Leong, 2017) and others reporting gender-neutral effects (Akobundu et al., 2025; Lestari et al., 2019).

Recent studies suggest that contextual and institutional factors, such as access to technology, professional development, and pedagogical support, may mediate gender-related differences. Lavidas et al. (2022) found that teachers' engagement with digital tools is influenced more by structural conditions than by gender alone. Similarly, Zourmpakis et al. (2024) and Uğraş et al. (2024) demonstrated that well-designed digital learning environments can promote equitable participation and reduce disparities.

Theoretical framework

Perspectives on technology adoption in education

Understanding teachers' adoption of instructional technologies requires more than a single explanatory lens. Educational technology research has consistently drawn on the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), and the Technological Pedagogical and Content Knowledge (TPACK) framework to explain how and why educators integrate digital tools into their practice. This study is grounded in these three complementary perspectives.

The Technology Acceptance Model (TAM) by Davis (1989) proposes that technology adoption is primarily shaped by perceived usefulness and perceived ease of use (Davis, 1989). In mathematics education, this implies that teachers are more inclined to adopt GeoGebra when they believe it enhances instructional effectiveness, improves conceptual understanding, and can be implemented without excessive difficulty within existing classroom structures. When teachers perceive the software as both pedagogically valuable and practically manageable, positive attitudes toward its integration are likely to develop.

While Ajzen (1991) explains TAM adoption in terms of cognitive evaluations of utility and usability, the Theory of Planned Behavior (TPB) broadens the analysis by emphasizing attitudes, subjective norms, and perceived behavioral control as determinants of intention and behavior (Ajzen, 1991). From this perspective, teachers' decisions to use GeoGebra are influenced not only by personal beliefs but also by institutional expectations, access to professional development, and confidence in their technological competence. Gender-related differences in technology use, when observed, are therefore better understood as products of contextual and experiential conditions rather than inherent characteristics.

The TPACK framework opined by Mishra & Koehler (2006), further deepens this understanding by highlighting that effective technology integration depends on the intersection of technological knowledge, pedagogical knowledge, and content knowledge (Mishra & Koehler, 2006). In the case of GeoGebra, successful implementation requires more than technical familiarity; it demands the ability to align the software's dynamic features with appropriate teaching strategies and solid mathematical understanding. Empirical applications of TPACK, as suggested by Marange & Tatira (2024), demonstrate that variations in teachers' technological and pedagogical competencies can shape both their attitudes toward and actual use of GeoGebra.

Taken together, TAM, TPB, and TPACK offer a coherent and layered theoretical foundation. TAM clarifies how perceptions of usefulness and ease of use shape acceptance; TPB situates these perceptions within broader social and institutional influences; and TPACK explains the professional knowledge structures necessary for meaningful classroom integration. Collectively, these frameworks provide a comprehensive basis for examining teachers' attitudes and instructional decisions regarding GeoGebra use.

GeoGebra and students' learning outcomes

A substantial body of empirical research indicates that GeoGebra positively influences students' mathematical understanding, engagement, and achievement. Experimental and quasi-experimental studies conducted across different educational contexts consistently report improved learning outcomes in geometry, algebra, and related domains when GeoGebra is integrated into instruction (Arbain & Shukor, 2015; Gamage & Charles-Ogan, 2019). Several studies have also examined whether these outcomes vary by gender. Lestari et al. (2019) found that GeoGebra-assisted reciprocal peer tutoring significantly improved students' mathematical communication skills, with no significant gender differences or interaction effects.

Similar conclusions were reported by Akobundu et al. (2025) and Gamage & Charles-Ogan (2019), who observed that GeoGebra-supported instruction enhanced achievement while minimizing gender disparities. In contrast, Pavethira & Leong (2017) reported a statistically significant gender difference favoring male students, although both male and female learners demonstrated substantial gains. These mixed findings suggest that while GeoGebra generally supports equitable learning outcomes, gender effects may depend on instructional context, duration of intervention, and assessment design.

Methodological limitations are evident in some studies, including small sample sizes, short intervention periods, and narrow topic coverage (Küçük & Gün, 2023). Nonetheless, the consistency of positive outcomes across contexts reinforces GeoGebra's instructional value and underscores the importance of examining teachers' readiness and attitudes toward its use.

Teachers' attitudes toward GeoGebra and technology integration

Teachers' attitudes play a central role in determining the extent and effectiveness of technology integration in classrooms. Attitudes are commonly conceptualized as comprising emotional (affective), instructional (behavioral), and cognitive components, consistent with classical attitude theory (Triandis, 1971). Emotional attitudes reflect teachers' confidence, motivation, and anxiety; cognitive attitudes relate to beliefs about instructional effectiveness; and instructional attitudes influence classroom practices and sustained use. Empirical studies suggest that teachers with positive emotional and cognitive dispositions toward GeoGebra are more likely to integrate it meaningfully into instruction.

Ekwule et al. (2023) reported that teachers perceived GeoGebra as engaging and pedagogically valuable, although infrastructural challenges and limited ICT skills constrained effective implementation. These findings highlight a recurring gap between positive attitudes and actual classroom use, particularly in developing educational contexts. Lavidas et al. (2022) further demonstrated that teachers' engagement with technology-related initiatives is influenced by perceived relevance, usability, and workload. Such factors align closely with emotional and cognitive attitude domains, emphasizing the need for well-designed professional development and supportive institutional environments.

Gender differences in teachers' perceptions and technology use

Research on gender differences in teachers' attitudes toward educational technology presents mixed and sometimes contradictory results. Marange & Tatira (2024), using the TPACK framework, found that male teachers reported higher confidence and familiarity with educational technologies, including GeoGebra. Similarly, Munyaruhengeri et al. (2025) identified gender-based differences in teachers' perceptions of GeoGebra's effectiveness for visual understanding, although no significant differences were observed in broader cognitive or affective domains.

Conversely, several studies report minimal or no gender differences when access to training and resources is equitable (Akobundu et al., 2025; Gamage & Charles-Ogan, 2019). These findings suggest that observed disparities are often context-dependent rather than universal. Zourmpakis et al. (2024) demonstrated that well-designed digital learning environments can reduce gender gaps by supporting adaptive and inclusive learning experiences.

Theoretical explanations for these inconsistencies include variations in professional development opportunities, differences in measurement instruments, and contextual factors such as school infrastructure and institutional support. These explanations align with TAM and TPB, which emphasize situational and experiential influences over fixed gender characteristics.

GeoGebra, instructional practice, and contextual constraints

While teachers generally acknowledge the pedagogical value of GeoGebra, effective classroom integration remains influenced by contextual conditions. Studies conducted in Sub-Saharan Africa frequently cite challenges such as inadequate ICT infrastructure, unreliable power supply, limited access to computer laboratories, and insufficient professional development (Mensah et al., 2023; Atteh et al, 2023). These constraints affect both teachers' instructional practices and their sustained use of technology, regardless of gender. Emerging research on other digital tools supports this interpretation.

Uğraş et al. (2024) found that teachers respond positively to new technologies when they align with pedagogical goals and curricular demands. This reinforces the importance of examining teachers' cognitive and instructional attitudes alongside emotional readiness, particularly in resource-constrained contexts.

Rationale for the selected attitude domains: Conceptualization of teachers' attitudes

Guided by the theoretical frameworks, teachers' attitudes toward GeoGebra are conceptualized across three interrelated domains: emotional attitudes, instructional experiences, and cognitive beliefs. Emotional attitudes refer to teachers' feelings, confidence, motivation, and anxiety associated with GeoGebra use, reflecting the affective components emphasized in TAM and TPB (Ajzen, 1991; Davis, 1989).

Instructional experiences capture teachers' classroom practices, integration strategies, and perceptions of instructional effectiveness, aligning with the pedagogical and technological intersections highlighted in TPACK (Mishra & Koehler, 2006). Cognitive beliefs represent teachers' perceptions of GeoGebra's impact on students' understanding, reasoning, and problem-solving abilities, corresponding to perceived usefulness within TAM. Together, these domains provide a comprehensive and theoretically grounded basis for assessing teachers' attitudes toward GeoGebra.

RESEARCH METHODOLOGY

Research design and participants

This study adopted a quantitative descriptive–comparative research design to examine gender differences in mathematics teachers' attitudes toward the use of GeoGebra in instruction and learning. The design was appropriate because it enabled the systematic measurement, description, and comparison of attitudes between male and female teachers using numerical data. Both descriptive and inferential statistical techniques were employed to provide a comprehensive understanding of teachers' attitudes and to determine whether observed differences were statistically significant.

The population for the study comprised all mathematics teachers teaching at the Junior High School (JHS) and Senior High School (SHS) levels in the Dormaa East, Dormaa West, and Dormaa Central Municipalities in the Bono Region of Ghana. These municipalities were selected because they represent a mix of urban and semi-urban schools and have increasing exposure to ICT-based instructional tools, including GeoGebra. A purposive sampling technique was used to select schools and participants based on the availability of mathematics teachers with basic ICT exposure, accessibility, and willingness to participate.

Thirteen JHSs and five SHSs were selected, yielding a total sample of 108 mathematics teachers, consisting of 60 males (55.6%) and 48 females (44.4%). Of these, 58 teachers (53.7%) were from JHSs and 50 teachers (46.3%) were from SHSs. The sample size was considered adequate for analysis of variance procedures and met recommended thresholds for detecting medium effect sizes at a significance level of $\alpha = .05$ (Cohen, 1988).

Instruments

Data were collected using a structured, self-administered questionnaire developed from existing literature on teacher attitudes and technology integration. The instrument was informed by the Technology Acceptance Model, the Theory of Planned Behavior, and the Technological Pedagogical and Content Knowledge framework. It captured demographic information and measured teachers' emotional attitudes toward GeoGebra, instructional experiences with GeoGebra, and beliefs about its cognitive benefits for students. Responses were rated on a four-point Likert scale ranging from Strongly Agree to Strongly Disagree, with no neutral option to encourage clear and definite responses. Content validity was ensured through expert review by specialists in mathematics education and educational technology, while construct validity was supported through exploratory factor analysis, which confirmed a three-factor structure with acceptable factor loadings. Reliability analysis using Cronbach's alpha yielded coefficients of 0.81 for emotional attitudes, 0.84 for instructional experiences, and 0.79 for cognitive beliefs, with an overall reliability coefficient of 0.86, indicating good internal consistency.

Data collection was conducted over four weeks through in-person administration of questionnaires during staff meetings and professional development sessions. Of the 115 questionnaires distributed, 108 were fully

completed and used for analysis, resulting in a response rate of approximately 94%. Ethical approval was obtained from the relevant educational authorities, participation was voluntary, informed consent was secured, and respondents were assured of anonymity and confidentiality.

Data analysis

Data analysis was carried out using the Statistical Package for the Social Sciences (SPSS) Version 22. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize demographic characteristics and attitude responses. Inferential analysis involved analysis of variance (ANOVA) and Pearson correlation analysis was conducted to examine gender differences across emotional, instructional, and cognitive attitude domains. Assumptions of normality and homogeneity of variance were tested and satisfied, and effect sizes were calculated using partial eta-squared to determine the magnitude of observed differences. Measures to reduce response bias included assurances that there were no right or wrong answers, that responses would not affect professional standing, and that all data were collected anonymously for academic purposes only.

RESULTS

The results are organized into two main sections: descriptive statistics and inferential statistics. Descriptive statistics summarize respondents' demographic characteristics and their attitudes toward GeoGebra across three domains—emotional attitudes, instructional experiences, and beliefs about cognitive benefits. Inferential analysis examines whether gender differences exist in these attitude domains using analysis of variance (ANOVA). *Detailed item-level tables, figures, and analysis are provided as supplementary materials to enhance readability and reduce redundancy in the main text.*

Descriptive statistics

Demographic characteristics of respondents

Table 1 summarizes the demographic characteristics of the 108 mathematics teachers who participated in the study. The variables include gender, teaching level, academic qualification, and years of teaching experience.

Table 1

Demographic characteristics of respondents

Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	60	55.6
	Female	48	44.4
Teaching level	JHS	58	53.7
	SHS	50	46.3
Academic qualification	Diploma	25	23.1
	Bachelor's Degree	68	63.0
	Master's Degree	15	13.9
Years of teaching experience	1–5 years	20	18.5
	6–10 years	35	32.4
	11–15 years	30	27.8
	Above 15 years	23	21.3

Results from **Table 1** reflect a balanced representation across gender and teaching levels, with most respondents holding at least a bachelor's degree and varying levels of teaching experience.

Descriptive analysis of teachers' attitudes toward GeoGebra

Teachers' attitudes toward GeoGebra were assessed across three theoretically grounded domains: *Emotional Attitudes*, *Instructional Experiences*, and *Cognitive Benefits*. This multidimensional operationalization aligns with classical attitude theory (Triandis, 1971) and contemporary technology adoption models such as TAM (Davis, 1989) and TPB (Ajzen, 1991), which emphasize affective, behavioral, and cognitive components of technology acceptance. The four-point Likert scale was structured such that lower mean scores reflected stronger agreement and thus more positive attitudes.

The tripartite structure is also consistent with research in mathematics education that distinguishes teachers' emotional readiness, instructional competence, and beliefs about student learning outcomes when integrating dynamic geometry software (Majerek, 2014; Sangwin, 2007; Sevimli & Ünal, 2022).

Attitude domains and scoring

Teachers' attitudes toward GeoGebra were measured across three domains: (a) emotional attitudes, (b) instructional experiences, and (c) beliefs about GeoGebra's cognitive benefits for students. Responses were rated on a four-point Likert scale ranging from 1 (Strongly Agree) to 4 (Strongly Disagree). Lower mean scores, therefore, indicate more positive attitudes (See [Appendix 1, 2 and 3](#)). *Item-level frequency distributions and graphical representations are reported as supplementary materials.*

Summary of frequency distributions across domains

The overall responses, as indicated in [Table 2](#) shows favorable perceptions of GeoGebra across all three domains, with the strongest endorsement observed for beliefs about its cognitive benefits. The distribution of responses demonstrates overwhelmingly favorable perceptions of GeoGebra across all three domains.

- Emotional attitudes: 68.4% of teachers either strongly agreed or agreed that GeoGebra positively influenced their emotional engagement with teaching mathematics.
- Instructional experiences: 68.2% reported positive instructional experiences.
- Cognitive benefits: 78.9% expressed agreement or strong agreement regarding GeoGebra's cognitive value for students.

Table 2

Summary of responses across the three attitude domains

Domain	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
Emotional attitudes	35.3	33.1	19.8	11.8
Instructional experiences	34.0	34.2	20.6	11.2
Cognitive benefits	42.8	36.1	13.7	7.4

Noted: See [Appendix 1, 2 and 3](#)

The strongest endorsement emerged in the *Cognitive Benefits* domain (42.8% strongly agree), indicating that teachers most strongly associate GeoGebra with improved conceptual understanding and reasoning. This finding is consistent with substantial empirical evidence demonstrating GeoGebra's effectiveness in enhancing visualization and conceptual learning (Hohenwarter & Fuchs, 2004; Hohenwarter, 2008; Arbain & Shukor, 2015; Saha et al., 2010; Adesina & Sosanwo 2025; Chimuka, 2017).

Recent studies further confirm that GeoGebra enhances geometry achievement and conceptual clarity in African and Asian contexts (Asare & Atteh, 2022; Akobundu et al., 2025; Küçük & Gün, 2023). The strong cognitive endorsement observed in this study therefore aligns with international evidence that teachers recognize the pedagogical affordances of dynamic visualization tools (Abramovich, 2013; Dogan, 2011; Griffin, 2021).

Mean and standard deviation of attitude domains

[Table 3](#) shows the results of the mean scores suggest that teachers generally expressed positive emotional dispositions toward GeoGebra, reported favorable instructional experiences, and held particularly strong beliefs about its cognitive benefits for students. The mean scores (Emotional = 1.86; Instructional = 1.94; Cognitive = 1.73) further confirm strong positive attitudes, as all values fall below 2.00. The relatively low standard deviations (0.44–0.52) indicate consistency across respondents.

Table 3

Mean and standard deviation of teachers' attitudes toward GeoGebra

Domain	Mean (M)	Standard Deviation (SD)
Emotional attitudes	1.86	0.47
Instructional experiences	1.94	0.52
Cognitive benefits	1.73	0.44

Noted: See [Appendix 4](#)

The lowest mean score in the *Cognitive Benefits* domain (M = 1.73) reinforces the earlier frequency findings. This pattern reflects high perceived usefulness, a core determinant of technology adoption under TAM (Davis, 1989). Similar patterns have been reported among Ghanaian teachers integrating GeoGebra (Mensah, 2023; Mensah et al., 2023) and among broader teacher samples examining instructional technology acceptance (Lotey et al., 2023; Webb, 2026).

The findings also resonate with research on ICT integration in Ghana, which suggests growing professional recognition of digital tools as pedagogically transformative (Atteh et al., 2023; Voogt & Pelgrum 2005; Lagura, 2022).

Relationships among attitude domains

Pearson correlation analysis was conducted to examine relationships among the three attitude domains. The results from **Table 4** show moderate to strong positive relationships among the domains, indicating that favorable emotional attitudes and instructional experiences are associated with stronger beliefs about GeoGebra's cognitive benefits.

Table 4

Correlation matrix of attitude domains

Domain	Emotional	Instructional	Cognitive
Emotional attitudes	1.00	0.62	0.58
Instructional experiences	0.62	1.00	0.66
Cognitive benefits	0.58	0.66	1.00

Noted: All correlations are significant at $p < .01$.

The Pearson correlations indicate moderate to strong positive relationships among the three domains: *Emotional–Instructional*: $r = .62$, *Emotional–Cognitive*: $r = .58$, *Instructional–Cognitive*: $r = .66$. All correlations were significant at $p < .01$.

These relationships suggest that teachers' emotional engagement is closely connected to their instructional experiences and beliefs about cognitive outcomes. This interdependence reflects the integrated structure proposed by TPB (Ajzen, 1991), where attitudes toward behavior interact with perceived control and behavioral beliefs.

Moreover, the strong association between *Instructional Experiences* and *Cognitive Benefits* ($r = .66$) suggests that when teachers observe improved learning outcomes, their instructional confidence increases. This aligns with TPACK (Mishra & Koehler, 2006), which posits that successful technological integration strengthens both pedagogical competence and belief in instructional efficacy.

Comparable interrelationships have been reported in studies examining teachers' attitudes and instructional implementation of GeoGebra (Kratt, 2018; Ekwule et al., 2023; Marange & Tatira, 2024; Munyaruhengeri et al., 2025; Boyacı & Erdamar, 2023).

Assumption testing for inferential analysis

Before conducting inferential analyses, the assumptions underlying ANOVA were examined. Inspection of skewness and kurtosis values indicated approximate normality for all three domains. Levene's test for homogeneity of variance was non-significant ($p > .05$) across domains, confirming that the assumption of equal variances was met. Normality and homogeneity of variance assumptions were satisfied, validating the use of ANOVA. Methodological rigor in assumption testing enhances statistical credibility, a practice recommended in quantitative educational research (Lavidas et al., 2022).

Inferential analysis: Gender differences in attitudes toward GeoGebra

Hypothesis testing

A one-way analysis of variance (ANOVA) was conducted to test whether statistically significant differences existed between male and female mathematics teachers' attitudes toward GeoGebra across the three domains.

Descriptive statistics by gender

From **Table 5**, although minor differences were observed between male and female teachers, these differences were negligible: *Emotional*: Male (1.84), Female (1.89), *Instructional*: Male (1.92), Female (1.97), *Cognitive*: Male (1.71), and Female (1.75).

Table 5

Descriptive statistics of attitude domains by gender

Domain	Gender	Mean (M)	SD
Emotional attitudes	Male	1.84	0.48
	Female	1.89	0.46
Instructional experiences	Male	1.92	0.53
	Female	1.97	0.51
Cognitive benefits	Male	1.71	0.45
	Female	1.75	0.43

The similarity in mean scores suggests shared professional experiences and perceptions across genders. This finding aligns with research suggesting that gender differences in technology use diminish under conditions of equitable access and training (Zourmpakis et al., 2024; Marange & Tatira, 2024).

ANOVA results and effect sizes

The one-way ANOVA results presented in **Table 6** indicate that there were no statistically significant differences between male and female mathematics teachers across the three attitude domains: emotional attitudes, instructional experiences, and beliefs about cognitive benefits ($p > .05$ in all cases). Although minor variations in mean scores were observed, these differences were not statistically meaningful. Partial eta-squared values (.008–.015) indicate trivial effect sizes, suggesting gender explains less than 2% of variance in attitudes.

Table 6

ANOVA results comparing male and female teachers' attitudes toward GeoGebra

Domain	F	p-value	Partial η^2
Emotional attitudes	1.642	.203	.015
Instructional experiences	1.302	.256	.012
Cognitive benefits	0.842	.361	.008

*Noted: See **Appendix 5***

This result supports emerging literature indicating that gender is not a consistent predictor of teachers' instructional technology adoption (Chalaune & Subedi, 2020; Mensah et al., 2023; Halpern et al., 2025; Almusharraf & Almusharraf, 2021). It also reinforces TPB's assertion that contextual and normative factors, rather than demographic characteristics, shape behavioral intention (Ajzen, 1991).

Given Ghana's increasing emphasis on standardized teacher preparation and ICT training (Atteh et al., 2023), structural parity may mitigate traditional gender disparities observed in earlier technology studies. Overall, the results suggest that male and female teachers hold comparable perceptions of GeoGebra's emotional, instructional, and cognitive value.

Exploratory analyses

Additional exploratory analyses examined differences in attitudes based on teaching level (JHS versus SHS), years of teaching experience, and academic qualification. No statistically significant differences were found across these variables ($p > .05$). This suggests that positive attitudes toward GeoGebra are broadly distributed across professional categories.

Such uniformity may reflect growing institutional normalization of technology use in mathematics education (Voogt & Pelgrum 2005; Batiibwe, 2024). It also indicates that GeoGebra's perceived instructional value transcends generational or qualification-based divides.

Summary of results

Collectively, the findings demonstrate:

1. Strong positive emotional, instructional, and cognitive attitudes toward GeoGebra.
2. High perceived usefulness consistent with TAM (Davis, 1989).
3. Interrelated affective, cognitive, and experiential components consistent with TPB (Ajzen, 1991) and attitude theory (Triandis, 1971).
4. Gender neutrality in technology perception, aligning with contemporary empirical evidence (Marange & Tatira, 2024; Zourmpakis et al., 2024).
5. Broad professional acceptance across demographic categories.

The results reinforce extensive international evidence that GeoGebra enhances mathematics instruction and student understanding (Hohenwarter, 2008; Arbain & Shukor, 2015; Chimuka, 2017; Küçük & Gün, 2023; Akobundu et al., 2025).

The results show that mathematics teachers generally hold positive attitudes toward the use of GeoGebra across emotional, instructional, and cognitive domains. Beliefs about GeoGebra's cognitive benefits received the strongest endorsement. No statistically significant gender differences were observed in any domain, and the magnitude of observed differences was small. The three attitude domains were positively and significantly related, and no meaningful differences emerged based on teaching level, experience, or academic qualification. *Detailed item-level analyses are provided as supplementary materials.*

DISCUSSION

This study set out not merely to describe teachers' attitudes toward GeoGebra, but to understand the mechanisms underlying those attitudes and the absence of gender differences within the Ghanaian context. While the results indicate consistently positive perceptions across Emotional Attitudes, Instructional Experiences, and Cognitive Benefits, the more important question is *why* these attitudes are positive and *why* gender did not emerge as a significant differentiating factor.

Interpretation of the domain-level findings

Emotional attitudes

Teachers reported feeling confident, motivated, and enthusiastic when using GeoGebra. These findings reinforce earlier work highlighting emotional acceptance of the software as a catalyst for instructional innovation (Asare & Atteh, 2022; Mensah, 2023). However, rather than treating positive emotions as isolated outcomes, they can be interpreted as emergent properties of perceived competence and instructional success. When teachers observe improved student engagement and conceptual clarity, positive affect is reinforced. From a theoretical standpoint, TAM helps explain this pattern. High perceived usefulness (belief that GeoGebra improves learning) and perceived ease of use (low frustration, manageable preparation time) likely generate favorable emotional responses. In other words, emotional positivity is not incidental—it is structurally linked to cognitive evaluations of utility and usability.

Instructional experiences

Teachers' favorable instructional experiences—improved lesson clarity, engagement, and manageable integration—align with findings by Garba (2019). Yet the critical insight here is that instructional experience acts as a mediating mechanism between belief and sustained adoption. According to Marange & Tatira (2024) on TPACK, effective technology integration occurs when technological knowledge intersects with pedagogical and content knowledge. Finding shows that the teachers in this study appear to have reached a functional level of TPACK alignment, where GeoGebra meaningfully supports mathematical representation rather than serving as a superficial add-on. This alignment likely reduces instructional friction, thereby neutralizing potential gender disparities. Where training and professional exposure are standardized, competence becomes distributed across teachers regardless of gender.

Cognitive benefits

Findings on cognitive benefits received the strongest endorsement. Teachers perceived GeoGebra as enhancing conceptual understanding, visualization, reasoning, and critical thinking, consistent with Joshi & Singh (2020). This domain's prominence is theoretically significant. As opined by Davis (1989), within TAM, perceived usefulness is often the strongest predictor of behavioral intention. The strong endorsement of cognitive value suggests that teachers view GeoGebra not simply as engaging, but as pedagogically transformative.

Under Ajzen (1991), TPB strengthen positive attitudes toward behavior, increasing intention to use the technology. Importantly, when usefulness is clearly observable in classroom outcomes—particularly in contexts like Ghana where abstraction in algebra and geometry poses persistent challenges—gender may become theoretically irrelevant. Practical efficacy overshadows demographic distinctions.

Why gender did not influence attitudes

The absence of statistically significant gender differences contrasts with literature that reports inconsistent or context-dependent gender effects. Rather than interpreting this as a neutral finding, it warrants deeper contextual explanation.

First, Ghana's teacher education and professional development systems provide largely standardized exposure to instructional technologies. When access, training, and institutional expectations are equitable, structural barriers that historically produced gender gaps diminish. This interpretation aligns with contemporary extensions of TAM (Davis, 1989), which argue that gender effects weaken under conditions of equal technological competence and organizational support (Zourmpakis et al., 2024).

Second, TPB suggests that subjective norms and perceived behavioral control shape intention. In Ghanaian secondary education, professional identity is strongly linked to instructional effectiveness rather than gendered expectations. If institutional norms emphasize performance and student outcomes, both male and female teachers may feel similar normative pressure and agency to adopt effective tools. Thus, contextual professional culture may mediate gendered patterns of adoption.

Third, the small effect sizes (η^2 ranging from .008 to .015) suggest that variance in attitudes is explained more by shared institutional and pedagogical factors than by demographic variables. This aligns with Chalaune & Subedi (2020) and Mensah et al. (2023), who also found gender to be a weak predictor of teachers' willingness to integrate GeoGebra.

In this sense, the findings do not merely show that gender “does not matter”; they suggest that when systemic conditions—training, access, curricular alignment—are stable, theoretical gender differences predicted in earlier models may dissipate.

Theoretical contributions

This study extends TAM, TPB, and TPACK in three ways:

1. Integration of emotional and cognitive mechanisms: Emotional attitudes appear to stem from perceived usefulness and ease of use, reinforcing TAM's structural assumptions.
2. Contextual moderation of gender: The findings support the view that gender is a context-sensitive variable rather than a universal determinant of technology acceptance (Zourmpakis et al., 2024).
3. TPACK as a stabilizing framework: The strong alignment between GeoGebra's dynamic features and mathematics content suggests that when technological tools map directly onto disciplinary epistemology, adoption becomes pedagogically rational rather than socially differentiated (Mishra & Koehler, 2006; Marange & Tatira, 2024).

Practical implications

Since attitudes are already favorable across genders, intervention efforts should prioritize sustainability rather than persuasion. The goal is not to convince teachers of GeoGebra's value, but to support consistent integration. Strategies may include:

1. Structured mentoring systems
2. Curriculum-aligned GeoGebra repositories
3. Infrastructure improvement
4. Scheduled collaborative planning time

Such supports would help convert positive attitudes into routine pedagogical practice (Mensah, 2023; Batiibwe, 2024).

Limitations and future directions

The study relied on self-reported survey data, which may introduce social desirability bias. Additionally, the focus on selected municipalities limits broader generalization. Future research should:

1. Employ mixed-methods designs integrating observation and interviews
2. Conduct longitudinal studies to assess sustained integration
3. Examine links between teacher attitudes and student achievement
4. Explore emerging AI-supported mathematics tools (Uğraş et al., 2024)

Concluding reflection

This study demonstrates that Ghanaian mathematics teachers hold consistently positive Emotional Attitudes, Instructional Experiences, and beliefs about Cognitive Benefits regarding GeoGebra. More importantly, it shows that gender does not significantly structure these attitudes within this professional context (Mensah et al., 2023). Rather than viewing this as a simple null finding, it should be interpreted as evidence that equitable training, institutional norms, and pedagogical alignment can neutralize demographic disparities in technology acceptance. When usefulness is visible and competence is supported, adoption becomes a professional choice rather than a gendered one.

CONCLUSION AND RECOMMENDATIONS

This study set out to examine mathematics teachers' attitudes toward GeoGebra within Ghanaian Junior and Senior High Schools, with particular attention to emotional dispositions, instructional experiences, and beliefs about cognitive benefits. The findings provide consistent evidence that teachers hold strongly positive views across all three domains. Teachers expressed confidence and enthusiasm in using GeoGebra, reported constructive instructional experiences, and most notably, endorsed its cognitive value in promoting visualization, conceptual understanding, problem-solving, and higher-order reasoning. The strength and consistency of these perceptions suggest that GeoGebra is not viewed as a peripheral technological addition, but as a meaningful pedagogical resource aligned with contemporary, learner-centered mathematics instruction.

Interpreted through the *Technology Acceptance Model (TAM)*, the findings indicate high levels of perceived usefulness and perceived ease of use. Teachers clearly recognize GeoGebra's instructional value, particularly its capacity to make abstract mathematical concepts more accessible. At the same time, the absence of substantial frustration or implementation difficulty suggests that the software is regarded as manageable within classroom realities. These two core constructs of TAM help explain the strong positive attitudes observed across the emotional, instructional, and cognitive domains.

The results also align with the *Theory of Planned Behavior (TPB)*. Teachers' favorable attitudes appear to be reinforced by professional norms that emphasize instructional effectiveness and innovation. The absence of significant gender differences suggests that subjective norms and perceived behavioral control operate similarly for both male and female teachers. In other words, when institutional expectations, access to training, and professional development opportunities are relatively equitable, demographic characteristics such as gender become less predictive of technology-related attitudes. The findings therefore suggest that contextual and structural conditions—rather than inherent differences—shape teachers' intentions to integrate GeoGebra into their practice.

From the perspective of the *Technological Pedagogical and Content Knowledge (TPACK)* framework, the positive instructional experiences reported by teachers imply a functional intersection of technological, pedagogical, and content knowledge. Teachers appear able to align GeoGebra's dynamic features with appropriate teaching strategies and mathematical content. This alignment likely contributes to their confidence and sustained positive perceptions. The strong correlations among emotional attitudes, instructional experiences, and beliefs about cognitive benefits further suggest that effective pedagogical integration reinforces both affective and cognitive acceptance.

A particularly important contribution of this study is the finding that gender does not significantly influence teachers' attitudes toward GeoGebra. The statistical analyses revealed negligible effect sizes, indicating that male and female teachers hold comparable perceptions across all domains. This outcome challenges assumptions that gender-based differences in technology acceptance are inevitable and instead supports the view that equitable access to training, professional exposure, and institutional support can mitigate such disparities. In the Ghanaian context examined, teachers appear similarly positioned to adopt and benefit from digital instructional tools, reinforcing principles of inclusivity and equity in educational innovation.

Given that attitudes toward GeoGebra are already favorable, future interventions should shift from persuasion to implementation. Professional development efforts would likely be more impactful if they focus on strengthening practical integration strategies. Structured school-based mentoring, collaborative lesson planning sessions, curriculum-aligned repositories of GeoGebra activities, reliable ICT infrastructure, and dedicated planning time for technology-enhanced lessons are all critical. These systemic supports address the practical constraints that often hinder sustained technology integration, even when attitudes are positive.

Several limitations warrant consideration. The study relied on self-reported data, which may be influenced by social desirability bias. Additionally, the absence of classroom observations or usage analytics limits conclusions about the frequency and depth of actual GeoGebra implementation. The purposive sampling of selected municipalities also constrains broader generalization. Future research could adopt mixed-methods approaches that combine surveys with classroom observations and longitudinal tracking to examine how positive attitudes translate into sustained pedagogical practice and student outcomes.

Overall, this study contributes to the growing body of scholarship on technology acceptance in mathematics education within Ghana and the wider Sub-Saharan African context. By integrating TAM, TPB, and TPACK, the findings demonstrate that teachers' acceptance of dynamic mathematics software is shaped by perceptions of usefulness, professional norms, and pedagogical competence. The evidence suggests that gender equity in attitudes is attainable when structural conditions support balanced access and training. For policymakers and educational leaders, the implication is clear: strengthening institutional supports and professional capacity will be more consequential than focusing solely on attitudinal barriers. Through deliberate and sustained systemic investment, technology integration in mathematics classrooms can be both equitable and pedagogically transformative.

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Ethical statement

All procedures involving human participants followed established ethical standards and the principles of the 1964 Helsinki Declaration. Non-clinical studies that do not harm humans, animals, or the environment are exempt from formal ethics approval under relevant research directives and Higher Education Law No. 2547. Participation was voluntary, informed consent was obtained, and participants' information was kept confidential.

Competing interests

Author(s) declare no conflict of interest

Author contributions

Patrick Akwasi Anamuah Mensah: Research concept and design, collection and/or assembly of data, data analysis and interpretation, writing the article, critical revision of the article, and final approval of the article. Mary Osei Fokuo: Collection and/or assembly of data, writing the article, critical revision of the article, and final approval of the article. Ishmael Besing Karadaar: Data analysis and interpretation, writing the article, and final approval of the article. Joseph Junior Gurah: Writing the article, critical revision of the article, and final approval of the article. Ernest Damoah-Asante: Collection and/or assembly of data, writing the article, and final approval of the article. Bismark Ansu: Collection and/or assembly of data, writing the article, and critical revision of the article.

Data availability

The availability of data is upon a genuine request to the corresponding author.

AI disclosure

In preparing this manuscript, the authors utilized AI tool solely to enhance the clarity, coherence, and overall readability of the text. All content generated with the assistance of this tool was carefully reviewed, revised, and validated by the authors. The authors assume full responsibility for the accuracy, integrity, and final content of the publication.

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APPENDENCE

APPENDIX 1

Frequency and percentage distribution of teachers' emotional attitudes toward GeoGebra use

Item	Statement	SA	A	D	SD	Total	Interpretation
B1	I feel excited when using GeoGebra to teach mathematics.	50 (46.3%)	40 (37.0%)	12 (11.1%)	6 (5.6%)	108	Positive
B2	Using GeoGebra makes my mathematics lessons more interesting and lively.	48 (44.4%)	42 (38.9%)	12 (11.1%)	6 (5.6%)	108	Positive
B3	I feel confident using GeoGebra to demonstrate mathematical concepts.	44 (40.7%)	46 (42.6%)	13 (12.0%)	5 (4.6%)	108	Positive
B4	I enjoy integrating GeoGebra into my teaching activities.	45 (41.7%)	41 (38.0%)	15 (13.9%)	7 (6.5%)	108	Positive
B5	GeoGebra use reduces my anxiety when teaching complex topics.	42 (38.9%)	44 (40.7%)	16 (14.8%)	6 (5.6%)	108	Positive
B6	I feel that learning to use GeoGebra is frustrating.	10 (9.3%)	16 (14.8%)	48 (44.4%)	34 (31.5%)	108	Positive
B7	I am motivated to explore new mathematical ideas using GeoGebra.	52 (48.1%)	39 (36.1%)	11 (10.2%)	6 (5.6%)	108	Positive
B8	I prefer traditional methods to GeoGebra for teaching mathematics.	14 (13.0%)	18 (16.7%)	46 (42.6%)	30 (27.8%)	108	Positive

APPENDIX 2*Frequency and percentage distribution of teachers' instructional experiences with GeoGebra*

Item	Statement	SA	A	D	SD	Total	Interpretation
C1	GeoGebra helps me explain abstract mathematical concepts more clearly.	46 (42.6%)	44 (40.7%)	12 (11.1%)	6 (5.6%)	108	Positive
C2	I regularly incorporate GeoGebra in my mathematics lessons.	38 (35.2%)	45 (41.7%)	18 (16.7%)	7 (6.5%)	108	Positive
C3	I use GeoGebra to demonstrate geometric and algebraic relationships.	47 (43.5%)	40 (37.0%)	15 (13.9%)	6 (5.6%)	108	Positive
C4	GeoGebra enhances classroom interaction and student engagement.	49 (45.4%)	41 (38.0%)	12 (11.1%)	6 (5.6%)	108	Positive
C5	I find it difficult to use GeoGebra because of limited resources.	15 (13.9%)	19 (17.6%)	47 (43.5%)	27 (25.0%)	108	Positive
C6	GeoGebra makes lesson preparation more efficient.	42 (38.9%)	46 (42.6%)	14 (13.0%)	6 (5.6%)	108	Positive
C7	The use of GeoGebra improves my instructional delivery.	45 (41.7%)	43 (39.8%)	14 (13.0%)	6 (5.6%)	108	Positive
C8	I find GeoGebra time-consuming to integrate into lessons.	12 (11.1%)	18 (16.7%)	46 (42.6%)	32 (29.6%)	108	Positive

APPENDIX 3*Frequency and percentage distribution of teachers' beliefs about geogebra's cognitive benefits for students*

Item	Statement	SA	A	D	SD	Total	Interpretation
D1	GeoGebra enhances students' understanding of mathematical concepts.	55 (50.9%)	40 (37.0%)	10 (9.3%)	3 (2.8%)	108	Very Positive
D2	GeoGebra helps students visualize and explore mathematical ideas effectively.	52 (48.1%)	42 (38.9%)	10 (9.3%)	4 (3.7%)	108	Very Positive
D3	GeoGebra improves students' problem-solving and reasoning skills.	50 (46.3%)	43 (39.8%)	11 (10.2%)	4 (3.7%)	108	Very Positive
D4	Students become more active learners when GeoGebra is used in class.	49 (45.4%)	42 (38.9%)	12 (11.1%)	5 (4.6%)	108	Very Positive
D5	GeoGebra supports students' critical and analytical thinking skills.	53 (49.1%)	41 (38.0%)	10 (9.3%)	4 (3.7%)	108	Very Positive
D6	GeoGebra enhances students' retention of mathematical concepts.	51 (47.2%)	44 (40.7%)	9 (8.3%)	4 (3.7%)	108	Very Positive
D7	GeoGebra distracts students from focusing on core mathematical principles.	10 (9.3%)	15 (13.9%)	48 (44.4%)	35 (32.4%)	Positive	
D8	GeoGebra encourages students to make connections between topics.	50 (46.3%)	45 (41.7%)	9 (8.3%)	4 (3.7%)	108	Very Positive

APPENDIX 4*Mean and standard deviation of teachers' attitudes toward the use of Geogebra*

Domain	N	Mean (M)	Standard Deviation (SD)	Interpretation
Emotional Attitudes Toward GeoGebra Use	108	1.86	0.47	Positive
Instructional Experiences with GeoGebra	108	1.94	0.52	Positive
Beliefs About GeoGebra's Cognitive Benefits	108	1.73	0.44	Very Positive

APPENDIX 5*ANOVA results comparing male and female teachers' attitudes toward GeoGebra*

Domain	Source of Variation	Sum of Squares	df	Mean Square	F	Sig. (p-value)	Decision	Partial η^2
Emotional Attitudes	Between Groups	0.215	1	0.215	1.642	0.203	NS	.015
	Within Groups	13.755	106	0.130				
	Total	13.970	107					
Instructional Experiences	Between Groups	0.178	1	0.178	1.302	0.256	NS	.012
	Within Groups	14.452	106	0.136				
	Total	14.630	107					
Cognitive Beliefs	Between Groups	0.098	1	0.098	0.842	0.361	NS	.008
	Within Groups	12.296	106	0.116				
	Total	12.394	107					