Article

Volume 13 (2025), pp. 33-56
American Journal of STEM Education: Issues and Perspectives
Star Scholars Press
https://doi.org/10.32674/yf4dpp14

How ICT and Teacher Attitudes Shape Math Achievement: A Structural Equation Model from Ghana's Secondary Education

Jacob Arhin
Akrokerri College of Education, Ghana

Yarhands Dissour Arthur
Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana

Joseph Frank Gordon
Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana

ABSTRACT

In this study, we examine the impact of ICT integration on high school students' mathematics achievement, with a focus on the moderating role of teachers' attitudes toward technology. Data were gathered from 500 mathematics teachers using a multi-stage sampling method and analyzed using Structural Equation Modeling (SEM). Findings reveal a positive relationship between ICT use and mathematics performance. Notably, teachers' positive attitudes toward ICT significantly strengthen this effect, highlighting the importance of teacher disposition in effective technology integration. The study highlights the importance of professional development that enhances both technical ICT competencies and positive attitudes. These results provide key insights for educational policy and instructional strategies aimed at improving learning outcomes through technology

Keywords: ICT integration, high school education, mathematics achievement, professional development, SEM, teacher attitudes, technology

INTRODUCTION

In recent years, the integration of Information and Communication Technology (ICT) into education has gained global prominence as a strategy to enhance teaching and learning outcomes and to prepare students for the demands of a technology-driven 21st-century workforce. ICT tools—such as interactive whiteboards, educational software, and online platforms—offer innovative ways for teachers to deliver instruction and for students to engage with content (Rafique et al., 2022; Mushimiyimana et al., 2025). This shift toward digital learning environments reflects broader societal and economic transformations, where technological literacy is increasingly essential (Akpan et al., 2020).

Despite the recognized benefits of ICT in education, its integration in classrooms—particularly in mathematics education—faces persistent challenges. These include inadequate infrastructure, limited technical support, insufficient teacher training, and a general resistance to change among some educators (Wakil et al., 2023). Furthermore, socio-economic disparities continue to hinder equal access to digital tools, deepening educational inequalities across different school contexts (Orlando & Attard, 2016). Among the various factors influencing ICT integration, teachers' attitudes play a particularly pivotal role.

Research shows that positive attitudes toward ICT are associated with greater adoption and more effective use of digital tools in instructional practices (Hew & Brush, 2021). Conversely, negative or ambivalent attitudes can impede integration efforts, even in well-resourced environments (Papadakis et al., 2018). Teachers' attitudes are shaped by factors such as their beliefs about technology, perceived usefulness, self-efficacy, and the ease of use of ICT tools (Akpan et al., 2020; Pio et al.,2025).

Importantly, teacher attitudes may not only influence the use of ICT directly but may also moderate its effectiveness in improving student outcomes. As noted by Jiménez-Becerra and Segovia-Cifuentes (2020), moderation involves a variable that affects the strength or direction of the relationship between two other variables. In this context, understanding how teachers' attitudes influence the relationship between ICT integration and students' mathematics achievement is crucial. This study, therefore, seeks to examine the moderating role of teachers' attitudes in the relationship between ICT integration and mathematics achievement among high school students. By examining how teacher perceptions influence the impact of ICT on student learning, this research aims to provide policymakers, school leaders, and curriculum designers with valuable insights for promoting more effective and equitable use of technology in education.

This study aims to investigate the moderating effect of teachers' attitudes on the relationship between ICT integration and high school students' mathematics achievement. By investigating how teachers' perceptions influence the effectiveness of ICT use in mathematics instruction, the study aims to offer insights into strategies that can enhance both teaching practices and student outcomes. The remainder of this paper is organized as follows: the next section reviews existing literature on ICT integration in education and the role of teacher attitudes; the methodology section outlines the research design, participants, and instruments used; the results section presents the findings of the study; the discussion section interprets these results in the context of previous research; and the final section concludes with key implications, limitations, and recommendations for future research.

Problem Statement

The integration of Information and Communication Technology (ICT) in education has been recognized as a critical factor in enhancing teaching and learning processes. However, despite substantial investments in technological infrastructure and resources, the effective integration of ICT into classroom practices remains inconsistent. While numerous studies have established that teachers' attitudes towards ICT significantly influence their adoption and use of technology (Teo, 2011).

The precise mechanisms by which these attitudes affect ICT integration are not fully understood. Most existing studies have focused on identifying correlations rather than exploring the underlying processes that moderate this relationship (Najdabbasi & Pedaste, 2014; Teo, 2011). Most studies have treated teachers' attitudes and ICT integration as independent predictors of educational outcomes without considering the possibility that attitudes might moderate the impact of ICT on Pedagogical Content Knowledge (PCK) (Ngodu, et al., 2024).

Therefore, this study aims to fill these gaps by investigating how teachers' attitudes towards ICT moderate the relationship between ICT integration and mathematics achievement. By employing Structural Equation Modeling (SEM), this research will provide a nuanced understanding of the pathways through which teachers' attitudes influence the effectiveness of ICT integration.

Hypothesis

1. H1: There is a positive relationship between ICT integration and high school students' mathematics achievement.
2. H2: Teachers' positive attitudes towards ICT have a direct positive effect on high school students' mathematics achievement.

   H3: Teachers' attitudes towards ICT moderate the relationship between ICT integration and high school students' mathematics achievement

LITERATURE REVIEW

Conceptual Framework

In this study, we examine the intricate relationships among ICT integration, teachers' attitudes towards ICT, and students' mathematics achievement in high school. Specifically, we investigate how teachers' attitudes serve as both a direct influence and a moderating factor in these relationships. The study posits that higher levels of ICT integration and more positive attitudes towards ICT are associated with improved student performance in mathematics.

Additionally, we hypothesize that the effect of ICT integration on student achievement is contingent on the positivity of teachers' attitudes. Positive attitudes are expected to enhance the beneficial impact of ICT integration, while negative attitudes may mitigate these effects. Through a structural equation modeling approach, we aim to provide a nuanced understanding of the interplay between technology use and teacher perceptions in shaping student academic outcomes.

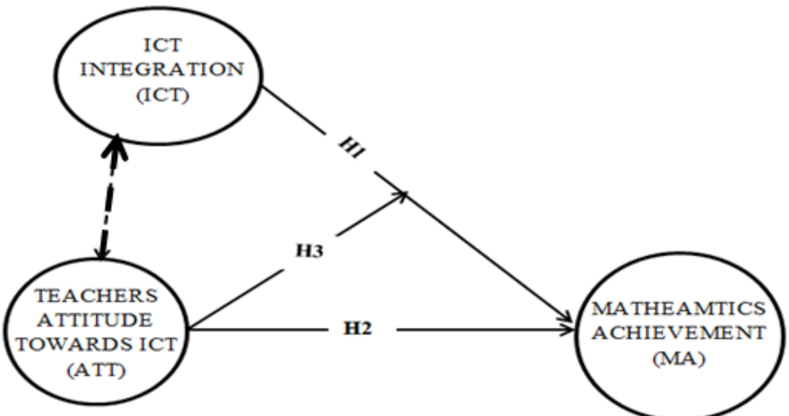

Figure 1: Conceptual framework of the study

→ **Direct effect**

- - - → **Indirect effect**

Positive Attitudes and ICT Integration

Teachers with positive attitudes toward ICT are significantly more inclined to adopt and integrate technology into their classrooms, which can enrich the educational experience through innovation and student engagement. Research consistently shows that attitude plays a pivotal role in shaping instructional behavior. For instance, Teo (2011) found that pre-service teachers who held favorable views about computer use were more likely to incorporate technology in their teaching. This highlights the importance of cultivating positive dispositions toward ICT early in teacher training programs, as these beliefs directly influence classroom practices. Such attitudes do more than encourage usage they transform pedagogy.

Teachers who view technology as beneficial are more likely to shift from traditional, lecture-based instruction to dynamic, interactive approaches. Makgati and Awolusi (2020) reported that teachers with positive attitudes toward technology often adopted innovative teaching strategies that fostered collaboration and engagement. Similarly, Ocak and Karanfil (2021) observed that these teachers were better positioned to implement student-centered practices, suggesting a clear link between attitude and pedagogical transformation.

Furthermore, positive teacher attitudes toward ICT have demonstrable impacts on student outcomes. Papadakis et al. (2021) evaluated a mobile self- and peer-assessment system, finding that effective integration of technology by motivated teachers led to heightened student engagement and academic achievement.

This supports the view that attitudes not only shape teaching methods but also directly influence learning effectiveness. In line with this, Najdabbasi and Pedaste (2014) found that teachers who perceived technology as a valuable educational tool were more inclined to create student-centered environments that promoted autonomy and deep learning. Such environments enable students to take ownership of their learning, leading to improved comprehension and long-term retention of content.

Positive attitudes also enhance teachers' ability to build students’ digital competencies. In Teo’s (2011) study, teachers who viewed ICT favorably were more likely to incorporate technology-rich activities that developed students' digital literacy skills. This point to the broader societal relevance of positive ICT attitudes, especially in preparing students for a technology-driven world. Importantly, such attitudes support differentiated instruction. Teachers who embrace ICT are better equipped to tailor their teaching to meet diverse learning needs. Ifinedo et al. (2020) found that teachers with positive attitudes toward technology were more likely to adopt ICT tools for personalized learning, enabling them to address varying student strengths and weaknesses effectively.

Taken together, these findings underscore the multifaceted benefits of fostering positive attitudes toward ICT. Beyond influencing adoption, such attitudes drive pedagogical innovation, support inclusive teaching practices, enhance student achievement, and build essential digital skills. Thus, professional development programs should prioritize both technical training and attitude development to maximize the impact of ICT integration in education.

Negative teachers’ Attitudes and ICT Integration

While positive attitudes toward ICT promote effective technology use, negative attitudes can significantly obstruct integration efforts in educational settings. Teachers who are skeptical of technology's benefits or who lack confidence in their abilities often resist incorporating ICT into their instructional practices. Amukoe et al. (2015) found that teachers who held negative beliefs about the educational value of ICT were less likely to use it meaningfully in their classrooms.

This reluctance was frequently linked to inadequate training and prior negative experiences, suggesting that building teacher confidence is critical to overcoming resistance. Negative attitudes can result in underutilization or superficial use of ICT. Instead of enriching instruction, technology may be relegated to routine administrative tasks, such as record-keeping or lesson preparation.

Nii et al. (2024) observed that many teachers restricted ICT use to such functions, missing opportunities to leverage digital tools for interactive learning. Similarly, Palak and Walls (2009) found that negative perceptions often led to minimal integration, where ICT served as a substitute rather than a transformative tool. Moreover, teachers with unfavorable views of technology may be less inclined to participate in professional development programs designed to enhance their ICT competencies.

This avoidance perpetuates a cycle of limited use and continued discomfort with technology. A lack of engagement with training opportunities not only stifles individual growth but also undermines broader institutional goals for digital innovation. The influence of school culture and systemic support cannot be overlooked in shaping teacher attitudes. Durff and Maryfriend (2019) emphasized that in schools where technology was undervalued or where support systems were lacking, negative attitudes toward ICT were more prevalent. In contrast, schools that fostered a culture of innovation and provided technical and pedagogical support saw more openness to ICT integration. These attitudes have consequences beyond the teacher.

When educators are reluctant to use technology, students miss out on opportunities to engage with digital tools that can enhance their learning experience. Timotheou et al. (2023) reported that in classrooms where teachers harbored negative attitudes toward ICT, students exhibited lower levels of engagement and academic achievement. This suggests a ripple effect, where teacher attitudes have a direct impact on student outcomes. To counteract these challenges, targeted interventions are necessary. Comprehensive professional development that addresses both the technical and affective dimensions of ICT use is crucial.

Nketiah-Amponsah et al. (2015) argued that training aligned with teachers' beliefs and classroom realities was more effective in shifting attitudes. When teachers' concerns are acknowledged and addressed, they become more open to adopting technology as a legitimate pedagogical tool. In sum, negative attitudes toward ICT create substantial barriers to integration, affecting not only teachers’ instructional practices but also student learning and overall school effectiveness.

Addressing these attitudes through well-designed support structures and professional development is essential to fostering a culture of meaningful technology use in education.

Teachers' Attitudes Towards Mathematics Achievement

Teachers’ attitudes toward mathematics play a pivotal role in shaping student learning experiences and academic outcomes. When educators demonstrate enthusiasm and confidence in teaching mathematics, they tend to adopt more engaging instructional practices, which in turn foster greater student interest and motivation. Abhilasha et al. (2022) found that teachers with positive attitudes toward mathematics created learning environments that actively engaged students, leading to improved performance. Similarly, Tabuk (2018) noted that a teacher’s enthusiasm for mathematics could directly influence student attitudes and learning behaviors. A key factor underpinning these positive attitudes is teacher self-efficacy, teachers’ belief in their ability to teach mathematics effectively.

High self-efficacy is linked to persistence, creativity, and a willingness to employ diverse instructional strategies. Blazar and Kraft (2017) demonstrated that teachers with high self-efficacy in mathematics were more likely to adopt effective, student-centered teaching practices, ultimately leading to improved student achievement. Teachers' attitudes are also closely related to their choice of instructional strategies. Those who view mathematics positively tend to use more varied, participatory, and student-centered approaches, while those with negative attitudes often rely on traditional, lecture-based methods.

Zee and Koomen (2016) found that teachers with favorable perceptions of mathematics were more inclined to implement innovative teaching strategies that supported conceptual understanding and active learning, both of which positively influenced student achievement. Beyond instructional methods, teachers' attitudes play a significant role in shaping the overall classroom climate. A supportive, encouraging environment often shaped by the teacher’s mindset can promote greater student confidence and participation. Mensah et al. (2013) highlighted that teachers who maintained positive attitudes fostered more inclusive and responsive classroom environments. These settings not only enhanced student engagement but also correlated with higher academic performance. Students’ perceptions of their teachers’ attitudes also matter. When students sense that their teachers are passionate and supportive, they are more likely to develop a similar outlook toward mathematics. Yıldız et al. (2020) found a strong relationship between students’ perceptions of their teachers’ positivity and their academic confidence and success. Positive teacher attitudes were shown to boost students’ self-efficacy and willingness to engage with mathematical challenges. Professional development plays a critical role in shaping and reinforcing teachers' attitudes toward mathematics. Programs that combine content mastery with effective pedagogical strategies can shift teacher mindsets and improve classroom practices.

Kartal (2020) emphasized that targeted professional development not only improved instructional effectiveness but also led to more positive teacher attitudes, which in turn supported better student outcomes. In conclusion, teachers' attitudes toward mathematics significantly influence both how they teach and how students learn. Positive attitudes foster dynamic, student-centered instruction and a supportive classroom environment, all of which contribute to improved student achievement. Enhancing these attitudes through professional development and supportive school cultures is essential for long-term success in mathematics education.

RESEARCH METHOD

The study adopted a quantitative research design, employing a cross-sectional survey approach. A cross-sectional survey approach is effective for capturing a snapshot of current attitudes, practices, and outcomes across different subjects and contexts (Creswell, 2014).

Table 1

Demographic Characteristics of the Study Group(n=500)

Demography		*Frequency (N)*	*Percentage (%)*
Gender	Male	425	85
	Female	75	15
		500	100
Age	25 - 34	135	27
	35 – 44	183	37
	45 -54	120	24
	55 -60	62	12
		500	100
Education background	Master degree	245	49
	Bachelor's degree`	255	51
	Others	0	0
		500	100

Source: Survey Data, 2024

To analyze the relationships between the variables and test the research hypotheses, Structural Equation Modeling (SEM) was utilized. Because SEM is a robust statistical technique that allows for the examination of complex relationships between observed and latent variables, providing a comprehensive understanding of direct and indirect effects (Kline, 2016).

Participant and procedure

This study provides a comprehensive overview of Senior High School mathematics teachers in four Ghanaian regions: Ashanti, Bono, Ahafo, and Bono East. The Ashanti Region is notable for its 134 schools and 2,680 mathematics teachers, highlighting robust educational infrastructure. The Bono Region has 37 schools with 555 teachers, maintaining a balanced teacher-student ratio. Ahafo, with 16 schools, has 240 mathematics teachers, showing a commitment to quality education despite fewer schools. Bono East, with 28 schools and 420 teachers, aligns with the national goal of enhancing mathematics education. Overall, the study includes 3,895 teachers across 215 schools.

A combination of stratified random sampling and proportionate sampling was used to ensure accurate representation from each region. Convenience sampling selected specific schools and teachers based on accessibility and willingness to participate, with a final sample size of 500 determined using the Yamane formula.

The demographic distribution shows a predominance of male participants (85%), with 425 males and 75 females. The largest age group is 35-44 years (37%), followed by 25-34 years (27%), 45-54 years (24%), and 55-60 years (12%). The majority of participants hold a Bachelor's degree (51%), with the remaining 49% holding a Master's degree. This distribution indicates a well-qualified and relatively uniform level of formal education among the teachers.

Data Collecting Instrument

A carefully designed questionnaire, aligned with the objectives of our study, was developed following a rigorous and systematic procedure. Initially, we clearly defined the variables and constructs of interest based on the theoretical framework and research objectives. To ensure content validity, we conducted an extensive literature review to identify relevant existing measures and adapted or modified them as necessary to suit our study context. Subsequently, new item questions were developed to directly assess each construct, ensuring alignment with the study's conceptual framework.

Teachers' attitude towards ICT (ATT), Towards ICT integration (ICT) and mathematics achievement (MA) were the three key factors considered in this study. The respondents were asked to select between 1 (strongly agree) to 5 (strongly disagree) on a five-point Likert scale used to quantify the variables. Ten measurement items were developed by the researchers, with the help of experts, for each of the constructs.

The development process incorporated expert reviews and pre-testing to refine the items for clarity, relevance, and comprehensiveness. Structural Equation Modeling (SEM) techniques were employed to validate the questionnaire items, including the use of confirmatory factor analysis (CFA) to assess the reliability and validity of the constructs. Through this approach, we ensured that each item exhibited strong factor loadings on the intended constructs, while poor-fitting items were revised or removed.

Validity and Reliability

To ensure the validity of the questionnaire, a pilot was conducted testing with a small sample of participants to assess the clarity, relevance, and comprehensibility of the items. Questionnaire by assessing its internal consistency using statistical measures such as Cronbach's alpha.

Reliability in measurement refers to its consistency over time and across different respondents. To assess the internal consistency of the questionnaire, Cronbach's alpha reliability testing was employed. The analysis was conducted using SPSS (v.23), where Cronbach's alpha (α) was calculated to evaluate the reliability of the measurement items. According to Pomegbe et al. (2020), a Cronbach's alpha score of at least 0.7 indicates acceptable internal consistency. Table 2 presents the Cronbach's alpha coefficients for the constructs measured in this study: Mathematics Achievement had α = 0.946, Teachers' Attitude Towards ICT had α = 0.943, and ICT Integration had α = 0.879. The table also includes the composite reliability and Average Variance Extracted (AVE) for each construct, further confirming the reliability and validity of the measurement items.

Table 2

Construct Reliability

Construct	*Items*	*Cronbach's Alpha (α)*	*Composite Reliability*	*Average Variance Extracted (AVE)*
Mathematics Achievement (MA)	6	0.946	0.961	0.758
Teachers' Attitude Towards ICT (ATT)	4	0.943	0.957	0.846
ICT Integration (ICT)	4	0.879	0.913	0.723

These high Cronbach's alpha values (all above 0.87) suggest that the questionnaire items were consistently understood and interpreted by respondents. This reinforces the internal consistency of each construct and supports the reliability of the measurement model used in the SEM analysis.

Exploratory factor analysis

The Exploratory Factor Analysis (EFA) was conducted using SPSS (ver. 23) to identify the underlying structure of the observed variables and their loading onto corresponding latent variables. The results of the EFA are summarized in Table 2, which shows the factor loadings of each item on their respective components.

The reliability coefficients for the constructs were all above the acceptable threshold of 0.7, indicating high reliability based on responses from high school mathematics teachers. Specifically, the Cronbach's alpha values ranged from 0.879 to 0.946 for the constructs, which include Mathematics Achievement (6 items), Teachers' Attitude Towards ICT (4 items), and ICT Integration (4 items).

Table 3

Rotated Component Matrix

	components		
	1	2	3
MA1	.917		
MA3	.744		
MA5	.905		
MA7	.907		
MA8	.885		
MA10	.711		
ATT6		.940	
ATT7		.935	
ATT8		.943	
ATT10		.945	
ICT1			.909
ICT3			.919
ICT4			.934
ICT5			.653

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was calculated to be 0.84, suggesting that the data is suitable for factor analysis. Bartlett's Test of Sphericity yielded a chi-square value of 3570.23 with 153 degrees of freedom and a p-value of less than 0.001, confirming that the correlation matrix is not an identity matrix and factor analysis is appropriate. The EFA utilized Principal Component Analysis (PCA) with Varimax rotation to simplify the factor structure. The rotation converged in 5 iterations, and the results are presented in Table 3. The table shows that all observed variables are correctly loaded onto their respective latent variables, with each item exhibiting substantial factor loadings. The cumulative variance explained by the three factors was 76.24%, indicating a robust factor structure.

Confirmatory analysis

The researchers utilized both theoretical and empirical foundations to develop a connection pattern for the study (Hair et al., 2010). To assess the reliability and validity of the measurement model, AMOS (version 23) was employed for confirmatory factor analysis (CFA).

This approach was chosen due to CFA's extensive capabilities in estimating a range of statistical tests and its applicability in various research contexts (Dogbe et al., 2020; Lahey et al., 2012). The CFA was conducted using IBM SPSS Amos (v.23) software. The measurement model was evaluated, and the fit indices for the model were as follows: CMIN = 134.142; degrees of freedom (df) = 80; CMIN/df = 1.677 (≤3.000), TLI = 0.969; CFI = 0.949; RMSEA = 0.041; RMR = 0.050; P-close = 0.060; GFI = 0.956. These fit indices indicate that the model provides a good fit to the observed data. The model fit indices (e.g., CFI = 0.949, RMSEA = 0.041) fall within recommended thresholds (Hair et al., 2013), confirming that the hypothesized structure fits the data well. This provides confidence in the construct validity of the measurement model and suggests that the theoretical structure is empirically supported. However, slight deviations in RMR suggest minor model refinement could be explored in future studies.

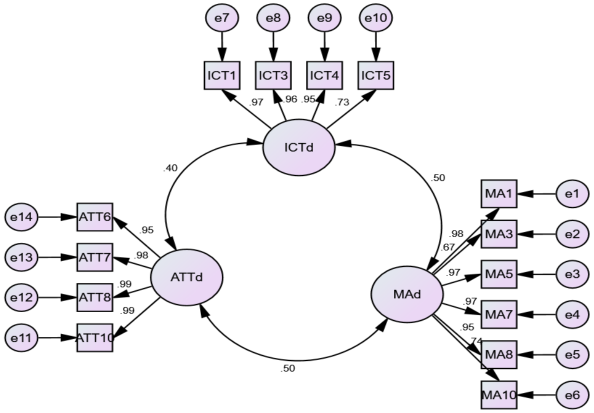

Figure 2: Diagram of confirmatory estimate analysis

Table 4
Confirmatory factor analysis

Variable	
Mathematics Achievement (MA): CA=.946, CR=.961 & AVE=0.758	*Loading*
MA1: How strongly do you agree that ICT tools (e.g. digital resources, educational apps) enhance high school students' mathematics achievement?	.917
MA3: How much do you agree that integrating ICT in teaching improves students understanding of high school mathematics concepts?	.744
MA5: How strongly do you agree that students' use of ICT tools (e.g., calculators, software) during mathematics lessons positively affects their academic performance?	.905
MA7: How much do you agree that ICT integration in mathematics teaching reflects the effectiveness of modern educational approaches?	.907
MA8: To what degree do you perceive that the use of ICT tools in mathematics lessons enhances students' self-confidence and sense of accomplishment?	.885
MA10: To what extent do you think that integrating ICT into teaching methods and curriculum design improves high school mathematics achievement?	.711
Teachers' Attitude Towards ICT (ATT): CA=.943, CR=.957 & AVE=0.846	
ATT6: How much do you enjoy exploring and learning about new technological tools that can enhance teaching?	.940
ATT7: To what degree do you believe that technology can help address the diverse learning needs of students?	.935
ATT8: How strongly do you agree that integrating technology into education can improve student outcomes?	.943
ATT10: How much do you agree that embracing technology in education is crucial for staying relevant as an educator?	.945
ICT Integration (ICT): CA=.879, CR=.913 & AVE=0.723	
ICT1: To what extent do you believe that ICT integration positively impacts students' understanding of mathematical concepts?	.909
ICT3: To what degree do you perceive that students' engagement in mathematics lessons increases due to the incorporation of ICT?	.919
ICT4: How strongly do you agree that ICT facilitates personalized learning experiences for students in mathematics?	.934
ICT5: To what extent do you believe that ICT integration positively impacts students' motivation to learn mathematics?	.653

Convergent Validity

Convergent validity evaluates the extent to which two measures of the same construct are correlated. This is assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). According to Hair et al. (2010), CR should exceed 0.70 to indicate good convergent validity, while AVE should be greater than 0.50 to ensure that a substantial amount of the variance is captured by the construct items. The provided data shows the CR and AVE values for the constructs as outlined in Table 5.

Table 5

Convergent Validity Assessment

Construct	*CR*	*AVE*
ICT Integration	0.967	0.728
Teachers' Attitude Towards ICT	0.926	0.657
Mathematics Achievement	0.984	0.801

The AVE for Mathematics Achievement (0.758) exceeds the threshold of 0.50, indicating that the majority of the variance in the observed items is explained by the latent construct. This suggests the items are strongly related to the underlying concept of mathematics achievement, thus reinforcing the convergent validity of the scale

Discriminant Validity

Discriminant validity is assessed by comparing the square root of AVE (√AVE) for each construct with the inter-construct correlation coefficients. Discriminant validity is considered achieved when the √AVE for each construct is greater than the highest correlation coefficient between constructs (Arthur et al., 2021). The summary of the discriminant validity analysis is presented in Table 6.

Table 6

Discriminant Validity Assessment

Construct Pair	Correlation (r)	AVE	√AVE
ICT Integration		0.728	0.854
Teachers' Attitude Towards ICT		0.657	0.811
Mathematics Achievement		0.801	0.896
ICT Integration ↔ Teachers' Attitude Towards ICT	0.120		
ICT Integration ↔ Mathematics Achievement	0.253		
Teachers' Attitude Towards ICT ↔ Mathematics Achievement	0.153		

The results show that the √AVE for each construct is higher than the highest correlation coefficient, indicating that discriminant validity is achieved. The analysis supports the robustness of the measuring methodology, with no evidence of multicollinearity affecting the model estimation (Dogbe et al., 2020)

RESULTS

Following the evaluation of the measurement model's fit, the data underwent further analysis to examine the moderating effect within the study's framework. This analysis was conducted by estimating various structural models using IBM SPSS Amos 23. The path estimates for the direct and moderating effects are depicted in Figure 3 and summarized in Table 7.

Direct Effect

Path analysis was utilized to explore the correlations or covariances between variables within a Structural Equation Modeling (SEM) framework. This analysis aimed to ascertain the proportion of covariance attributable to theoretically implied causal influences. Covariance-based SEM using Amos (v.23) software was employed to determine the path coefficients. A bias-corrected (BC) percentile bootstrapping technique was utilized, with 5,000 bootstrap samples and a 95% confidence level. The outcomes of the independent variables' direct influence on the dependent variable (Mathematics Achievement) are presented in Table 7.

The direct path analysis showed that ICT Integration (ICT), Teachers' Attitude towards ICT (ATT), and Mathematics Achievement (MA) have significant direct effects. The path estimate for ICT → MA indicated a statistically significant positive direct influence ($\beta = 0.217$; $p < .05$), suggesting that as teachers integrate ICT in teaching, students' mathematics achievement increases by approximately 21.7%.

H1: "*ICT Integration positively influences students' mathematics achievement"* was accepted based on these findings. Additionally, the analysis demonstrated a significant positive direct effect of Teachers' Attitude Towards ICT (ATT) on ICT Integration (ICT). The path estimate of $\beta = 0.180$ ($p < .05$) indicates that positive attitudes towards ICT significantly enhance ICT integration in teaching practices.

H2: "*Teachers' Attitude Towards ICT positively influences ICT Integration*" was supported by the study findings. Further, the study revealed a significant positive direct effect of ICT Integration on Teachers' Attitude Towards ICT, with a path estimate of $\beta = 0.163$ ($p < .05$). This suggests that increased use of ICT in teaching enhances positive attitudes towards ICT among teachers.

Table 7:
Direct Path Estimate

Direct Paths	*Unstandardized Estimate (β)*	*CR*	*SE*	*p-value*
ICT → MA	0.217	4.912	0.044	0.001
ATT → ICT	0.180	3.670	0.049	0.001
ICT → ATT	0.163	3.139	0.052	0.002

Note. Model Fit Indices: CMIN = 134.142; df = 80; CMIN/df = 1.677 (≤ 3.000), TLI = .969; CFI = .949; RMSEA = .041; RMR = .050; P-close = .060; GFI = .956.

This implies that increased ICT integration by teachers is associated with a 21.7% increase in students' mathematics achievement. This effect size, while moderate, suggests that technology can play a meaningful role in enhancing learning outcomes when effectively incorporated into teaching practices. These findings align with constructivist learning theories, which emphasize the role of digital tools in facilitating active learning and deeper conceptual understanding.

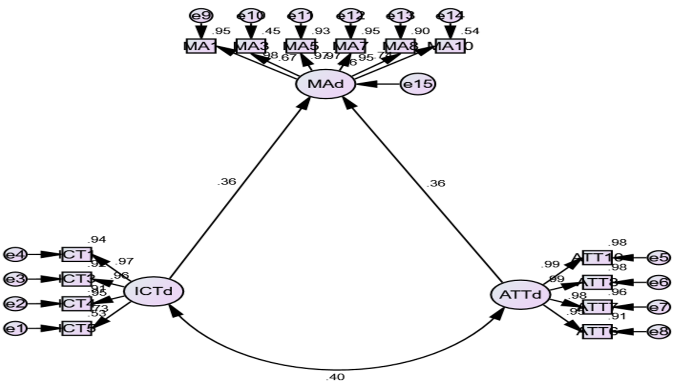

Figure 2: diagram of direct path

Moderating Path Estimates

The moderating effect of Teachers' Attitude Towards ICT (ATT) was explored as an additional hypothesis path in the study. The relationship between ICT Integration and Mathematics Achievement (MA) was examined to determine the moderating role of teachers' attitudes towards ICT. Table 8 indicates that the interaction between ICT Integration and Teachers' Attitude Towards ICT had a statistically significant positive moderating effect on Mathematics Achievement ($\beta = .095$, $p < .05$).

This suggests that the positive impact of ICT Integration on Mathematics Achievement increases by approximately 9.5% as teachers' attitudes towards ICT become more positive. Therefore, the hypothesis that "Teachers' Attitude Towards ICT moderates the relationship between ICT Integration and Mathematics Achievement" was supported.

H3: "*Teachers' attitudes towards ICT moderate the relationship between ICT integration and high school students' mathematics achievement*" was confirmed.

Table 8

Moderating effect of Teachers attitude towards ICT integration and Mathematics achievement

Moderating Path	*Estimate (β)*	*Standard Error*	*Lower Bias-Corrected*	*Upper Bias-Corrected*	*p-value*
ICT × ATT → MA	.095	.038	.020	.170	.012

While the moderating effect of teachers' attitudes on the ICT-Mathematics Achievement relationship was statistically significant, the relatively small effect size ($\beta = 0.095$) suggests that attitudes, while influential, may not be the sole or dominant factor enhancing ICT's impact. Other contextual factors such as infrastructure availability, class size, or digital competence may also play key roles.

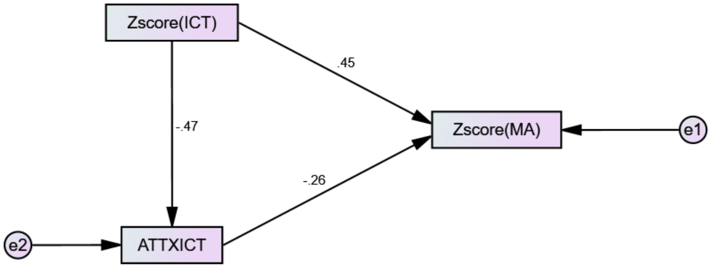

Figure 2: Diagram of moderating path estimate

DISCUSSION AND CONCLUSIONS

The study found that teachers' positive attitudes towards ICT have a direct and significant impact on students' mathematics achievement. By analyzing both direct and interaction effects within a structural equation modeling framework, the study contributes to a more nuanced understanding of how technology and human factors jointly shape learning outcomes in mathematics education.

The results provide insights into how technology integration in education, combined with teachers' attitudes, affects student outcomes in mathematics. The hypotheses and findings are discussed below:

1. Hypothesis 1: There is a positive relationship between ICT integration and high school students' mathematics achievement.
2. Hypothesis 2: Teachers' positive attitudes towards ICT have a direct positive effect on high school students' mathematics achievement.
3. Teachers' attitudes towards ICT moderate the relationship between ICT integration and high school students' mathematics achievement.

Effect of ICT Integration on High School Students' Mathematics Achievement

The study demonstrated a positive relationship between ICT integration and students' mathematics achievement. This finding is consistent with existing literature, which highlights the educational benefits of integrating technology into classroom instruction. For instance, Orlando and Attard (2016) found that effective ICT use can enhance students' learning experiences and academic performance, particularly in mathematics.

Similarly, Nii et al. (2024) demonstrated that the integration of digital tools in mathematics instruction improves student engagement and understanding of complex mathematical concepts. These results underscore the potential of ICT to facilitate better learning outcomes in mathematics when properly implemented.

Impact of Teachers' Attitudes Towards ICT on High School Students' Mathematics Achievement

The study found that teachers' positive attitudes towards ICT have a direct and significant impact on students' mathematics achievement. This finding aligns with research by Rafique et al. (2022), who emphasized the crucial role of teachers' perceptions in determining the effectiveness of technology in the classroom.

Teachers with positive attitudes towards ICT are more likely to implement it effectively, resulting in improved student learning outcomes. This highlights the importance of fostering positive attitudes among educators towards technology to maximize its benefits for students.

Moderating Role of Teachers' Attitudes Towards ICT on the Relationship Between ICT Integration and Mathematics Achievement

The study revealed that teachers' attitudes towards ICT significantly moderate the relationship between ICT integration and students' mathematics achievement. Specifically, the positive impact of ICT integration on mathematics achievement is amplified when teachers hold favorable attitudes towards technology.

The statistically significant moderation ($\beta = .095$, $p = .012$) indicates that the effect of ICT integration on student achievement is not uniform but rather depends on the teacher's attitude. This supports the view that technology alone is insufficient; its effectiveness is contingent on the teacher’s willingness and enthusiasm to integrate it meaningfully (Rafique et al., 2022). It also implies that schools should invest in changing attitudes alongside infrastructure development.

In addition to the direct influence of ICT use, our findings also highlight the significant role of teachers' attitudes. Specifically, teachers who hold positive attitudes toward ICT tend to foster greater student achievement in mathematics. This relationship suggests that teacher mindset is not merely a contextual factor, but a pivotal element shaping the impact of technology in the classroom.

IMPLICATIONS

These findings have significant implications for educational practice. To optimize the benefits of ICT integration in high school mathematics education, it is essential to focus on both the technical aspects of ICT and teachers' attitudes towards its use. Professional development programs should include training that addresses both the practical application of ICT tools and the cultivation of positive attitudes towards technology. By creating a supportive environment that encourages positive attitudes towards ICT, educators can enhance its effectiveness and contribute to better student outcomes. Collectively, these results emphasize the intertwined nature of technology use and teacher perception in shaping student outcomes. Accordingly, the implications for practice are twofold and merit serious consideration by policymakers and school administrators.

In conclusion, this study provides evidence that the integration of ICT positively influences the mathematics achievement of high school students, with teachers' attitudes towards ICT playing a moderating role. While ICT integration alone has the potential to improve student performance, its effectiveness is significantly enhanced when teachers have a positive attitude towards technology.

REFERENCES

Abhilasha, M., Ahmed, S., & Sing, N. V. (2022). Impact of teachers' attitude on students' mathematics achievement in Meitei Pangal community of Manipur. *Journal of Positive School Psychology, 6*(9), 4713–4725. http://journalppw.com

Akpan, I. J., Soopramanien, D., & Kwak, D. H. (Austin). (2020). Cutting-edge technologies for small business and innovation in the era of COVID-19 global health pandemic. *Journal of Small Business & Entrepreneurship, 33*(6), 607–617. https://doi.org/10.1080/08276331.2020.1799294

Amuko, S., Miheso, M., & Ndeuthi, S. (2015). Opportunities and challenges: Integration of ICT in teaching and learning mathematics in secondary schools, Nairobi, Kenya. *Journal of Education and Practice, 6*(24), 1–6. https://files.eric.ed.gov/fulltext/EJ1078869.pdf

Arthur, P., Ryu, D., & Haffari, G. (2021). Multilingual simultaneous neural machine translation. In *Findings of the Association for Computational Linguistics: ACL-IJCNLP 2021* (pp. 4758–4766). Association for Computational Linguistics. https://aclanthology.org/2021.findings-acl.420

Blazar, D., & Kraft, M. A. (2017). Teacher and teaching effects on students' attitudes and behaviors. *Educational Evaluation and Policy Analysis, 39*(1), 146–170. https://doi.org/10.3102/0162373716670260

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.

Dogbe, C. S. K., Tian, H., Pomegbe, W. W. K., Sarsah, S. A., & Otoo, C. O. A. (2020). Effect of network embeddedness on innovation performance of small and medium-sized enterprises: The moderating role of innovation openness. *Journal of Strategy and Management, 13*(2), 181–197. https://doi.org/10.1108/JSMA-07-2019-0126

Durff, L., & Carter, M. (2019). Overcoming second-order barriers to technology integration in K–5 schools. *Journal of Educational Research and Practice, 9*(1), 17. https://doi.org/10.5590/JERAP.2019.09.1.18

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long Range Planning, 46*(1–2), 1–12.

Ifinedo, E., Rikala, J., & Hämäläinen, T. (2020). Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices, and beliefs. *Computers & Education, 146*, 103760. https://doi.org/10.1016/j.compedu.2019.103760

Jiménez-Becerra, I., & Segovia-Cifuentes, Y. de M. (2020). Models of didactic integration with ICT mediation: Some innovation challenges in teaching practices. *Culture and Education, 32*(3), 399–440. https://doi.org/10.1080/11356405.2020.1785140

Kartal, B. (2020). Pre-service science and mathematics teachers' teaching efficacy beliefs and attitudes toward teaching: A partial correlation research. *Australian Journal of Teacher Education, 45*(9), 42–61.

Kline, R. B. (2016). *Principles and practice of structural equation modeling* (4th ed.). Guilford Press.

Lahey, B. B., Applegate, B., Hakes, J. K., Zald, D. H., Hariri, A. R., & Rathouz, P. J. (2012). Is there a general factor of prevalent psychopathology during adulthood? *Journal of Abnormal Psychology, 121*(4), 971.

Lawrence, J. E., & Tar, U. A. (2018). Factors that influence teachers' adoption and integration of ICT in teaching/learning process. *Educational Media International, 55*(1), 79–105. https://doi.org/10.1080/09523987.2018.1439712

Makgati, M. O., & Awolusi, O. D. (2020). The influence of Information Communication Technology (ICT) integration on teaching and learning in South African schools. *Journal of Education and Vocational Research, 10*(2), 47–64. https://doi.org/10.22610/jevr.v10i2(V).3023

Mensah, J. K., Okyere, M., & Kuranchie, A. (2013). Student attitude towards mathematics and performance: Does the teacher attitude matter? *Journal of Education and Practice, 4*(3), 132. http://www.iiste.org/Journals/index.php/JEP/article/view/4372

Mushimiyimana, J. B., Nzabalirwa, W., Ndayambaje, I., & Lazareva, A. (2025). ICT integration in Rwandan education: A scoping review of opportunities and challenges. *African Journal of Educational Research and New Technologies, 6*(1), Article 21. https://doi.org/10.51867/ajernet.6.1.21

Najdabbasi, N., & Pedaste, M. (2014). Integration of technology into classrooms: Role of knowledge and teacher beliefs. In C. Stephanidis (Ed.), *HCI International 2014 – Posters' Extended Abstracts. Communications in Computer and Information Science* (Vol. 435). Springer. https://doi.org/10.1007/978-3-319-07854-0_21

Ngodu, A., Ndibalema, P. M., & William, F. (2024). Understanding stakeholders' perception on integrating ICT in teaching and learning science subjects: Experiences from Tanzanian secondary schools. *Educational Technology Quarterly.* https://doi.org/10.55056/etq.714

Nii Akai Nettey, J., Osei Mensah, R., Asafo-Adjei, R., & Adiza Babah, P. (2024). Analyzing the challenges basic school teachers face in integrating information and communication technology into teaching and learning activities in a developing country. *Cogent Education, 11*(1). https://doi.org/10.1080/2331186X.2024.2364544

Nketiah-Amponsah, E., Asamoah, M. K., Allassani, W., & Aziale, L. K. (2015). Examining students' experience with the use of some selected ICT devices and applications for learning and their effect on academic performance. *Journal of Education and Practice, 6*(24). https://www.iiste.org/Journals/index.php/JEP/article/view/24451

Ocak, G., & Karanfil, B. (2021). Teachers' perceptions of their technological competence in the learning and teaching process. *Malaysian Online Journal of Educational Technology, 9*(4), 14–30. https://doi.org/10.52380/mojet.2021.9.4.221

Orlando, J., & Attard, C. (2016). Digital natives come of age: The reality of today's early career teachers using mobile devices to teach mathematics. *Mathematics Education Research Journal, 28*(1), 107–121. https://doi.org/10.1007/s13394-015-0159-6

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2018). The effectiveness of computer and tablet-assisted intervention in early childhood students' understanding of numbers: An empirical study conducted in Greece. *Education and Information Technologies, 23*(5), 1849–1871. https://doi.org/10.1007/s10639-018-9693-7

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2021). Teaching mathematics with mobile devices and the Realistic Mathematical Education (RME) approach in kindergarten. *Advances in Mobile Learning Educational Research, 1*(1), 5–18. https://doi.org/10.25082/AMLER.2021.01.002

Pio, E., Chadzimura, C. C., & Badza, R. S. (2025). Digital initiatives in education: The impact of information and communication technology (ICT) use in classroom-based teaching and learning within the Education 5.0 mantra. *International Journal of Latest Technology in Engineering, Management & Applied Science, 16*(1), 298–306. https://doi.org/10.51583/IJLTEMAS.2025.1401032

Pomegbe, W. W. K., Li, W., Dogbe, C. S. K., & Otoo, C. O. A. (2020). Enhancing the innovation performance of small and medium-sized enterprises through network embeddedness. *Journal of Competitiveness, 12*(3), 156–171. https://doi.org/10.7441/joc.2020.03.09

Rafique, T., Mahmood, S., Butt, F. S., & Mehmood, T. (2022). The mediating role of absorptive capacity and learning networks in the relationship between inter-organizational learning and innovation capability. *Journal of Positive School Psychology, 6*(9), 1917–1927. http://journalppw.com

Tabuk, M. (2018). Prospective primary school teachers' attitudes towards teaching mathematics. *Journal of Education and Learning, 7*(4), 225. https://doi.org/10.5539/jel.v7n4p225

Teo, T. (2011). Factors influencing teachers' intention to use technology: Model development and test. *Computers & Education, 57*(4), 2432–2440. https://doi.org/10.1016/j.compedu.2011.06.008

Timotheou, S., Miliou, O., Dimitriadis, Y., Villagrá Sobrino, S., Giannoutsou, N., Cachia, R., Martínez Monés, A., & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies, 28*, 6695–6726. https://doi.org/10.1007/s10639-022-11431-8

Wakil, A. A., Bornaa, C. S., & Boare, I. A. (2023). Integration of information and communication technology in the teaching and learning of mathematics in junior high schools in Tamale, Ghana. *East African Journal of Education Studies, 6*(3). https://doi.org/10.37284/eajes.6.3.1602

Yıldız, A., Baltacı, S., & Kartal, B. (2020). Examining the relationship between pre-service mathematics teachers' mathematical thinking level and attitude towards mathematics courses. *Acta Didactica Napocensia, 13*(2), 256–270. https://doi.org/10.24193/adn.13.2.17

Zee, M., & Koomen, H. M. Y. (2016). Teacher self-efficacy and its effects on classroom processes, student academic adjustment, and teacher well-being: A synthesis of 40 years of research. *Review of Educational Research, 86*(4), 981–1015. https://doi.org/10.3102/0034654315626801

Bios

JACOB ARHIN is a PhD Candidate in the Department of Mathematics Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), and an assistant lecturer at Akrokerri College of Education, Ghana. His major research interests include ICT integration in teaching and learning of mathematics and pedagogical approaches in teaching mathematics and STEM education. Email: arhin.jacob@yahoo.com

YARHANDS DISSOUR ARTHUR PhD, is an Associate Professor in the Department of Mathematics, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Ghana. His major research interests include ICT integration in Mathematics Education, History of mathematics, STEM education, realistic mathematics education, and problem-solving. Email: ydarthur@aamusted.edu.gh

JOSEPH FRANK GORDON, PhD, is a lecturer in the Department of Mathematics, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Ghana. His major research interests include ICT integration in mathematics, pedagogical practices, formative assessment, and manipulatives in mathematics education. Email: jfgordon@aamusted.edu.gh

Acknowledgements
This study is based on a part of the doctoral thesis entitled "A structural modeling approach to unpacking the influence of teachers' variables on ICT integration on high school mathematics achievement in Ghana". It was done as part of the academic requirement for PhD (Mathematics Education) candidates for their program completion. The authors would like to thank the Heads of Department at the Faculty of Applied Sciences and Mathematics Education of AAMUSTED, Kumasi, and SHS teachers who contributed during the data collection for the successful completion of this research article. The authors would like to acknowledge the use of OpenAI's ChatGPT in arranging the references list in alphabetical order for us.

Author contributions: All the authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. Authors approve final version of the article.

Declaration of interest: No conflict of interest is declared by authors.

Ethics declaration: Authors declared that the research presented in this article has been conducted in accordance with the highest ethical standards and guidelines. The study was approved by the AAMUSTED Institutional Ethics and Research Committee of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) (Approval code: AAMUSTED/IERC/2024/14). Written informed consent was obtained from the Chairman of Institutional Ethical Review Committee, Heads of the Departments of mathematics education and lecturers, as well as from the teachers.

Funding: The authors received no financial support for the research and/or authorship of this article.