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Exploring the Link between Teaching Variables and Ghanaian Junior High School Mathematics Achievement: The Mediating Role of Teachers' Self – Efficacy

[1]Ernest Frimpong Akosah
[2]Yarhands Dissou Arthur
[3]Benjamin Adu Obeng
[1,2,3]*Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana*

ABSTRACT

This study investigates the mediating role of teachers' self-efficacy in the relationship between teacher knowledge, teaching quality, teaching experience, and students' mathematics achievement. Utilizing a quantitative research design, the study employs structural equation modeling (SEM) to analyze data collected from 507 junior high school mathematics teachers and their 5070 students across eight regions in Ghana. Participants were selected using a stratified purposive sampling technique. The data were analyzed using SPSS and AMOS version 23. The findings reveal that teacher knowledge significantly impacts students' mathematics achievement, while teaching quality and teaching experience also exhibit positive effects. Furthermore, teacher self-efficacy was found to partially mediate the relationships between teacher knowledge and mathematics achievement, as well as between teaching quality and mathematics achievement. These results highlight the critical role of teacher self-efficacy in enhancing mathematics education. The study underscores the importance of professional development programs that focus on improving teacher self-efficacy to boost students' performance in mathematics.

Keywords: teaching experience, teacher knowledge, teaching quality, teacher self-efficacy, mathematics achievement

INTRODUCTION

Over the past two decades, research on student mathematics achievement has intensified globally, with initiatives such as the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA) underscoring the critical role of mathematical literacy in preparing students for future challenges (OECD, 2021). Mathematics is not only essential for individual academic success but also pivotal for national competitiveness in an increasingly technological and data-driven world (Abdullah & Ahmed, 2022). The application of mathematics permeates all facets of human endeavor, fostering critical thinking, innovation, and problem-solving abilities (Akman, 2021; OECD, 2021). Despite the acknowledged significance of mathematics, persistent underperformance in the subject remains a global challenge, particularly in developing countries where educational resources and infrastructure are often inadequate (Asare et al., 2024). In Ghana, this issue is evident in both national assessments and international benchmarks, where students frequently score below average (TIMSS, 2019). Addressing this problem requires a comprehensive examination of various teacher-related variables, including teacher knowledge, teaching quality, teaching experience, and teacher self-efficacy. While the importance of these teacher variables in influencing educational outcomes is widely recognized, there is a paucity of research investigating their collective impact on mathematics achievement, particularly within the Ghanaian context. This study seeks to fill this gap by exploring the interplay between classroom variables and junior high school (JHS) mathematics teachers' self-efficacy on learners' mathematics achievement. Specifically, it examines how teachers' self-efficacy mediates the relationship between teacher knowledge, teaching quality, and teaching experience on students' mathematics achievement. The study also contributes to Sustainable Development Goal (SDG) 4 by proposing strategies to improve mathematics education through enhanced teacher efficacy and innovative pedagogical approaches.

Research Objectives and Hypotheses

1. **H1**: *Teacher knowledge has a direct positive effect on JHS students' mathematics achievement.*
2. **H2:** *Teaching quality has a direct positive effect on JHS students' mathematics achievement.*
3. **H3**: *Teaching experience has a direct positive effect on JHS students' mathematics achievement.*
4. **H4:** *teachers' self - efficacy mediates the relationship between teacher knowledge and JHS students' mathematics achievement.*

5. **H5:** *teachers' self - efficacy mediates the relationship between teaching quality and JHS students' mathematics achievement.*
6. **H6:** *teachers' self - efficacy mediates the relationship between teaching experience and JHS students' mathematics achievement.*

LITERATURE REVIEW

Theoretical Framework

This study adopts Bandura's Social Cognitive Theory (SCT) to conceptualize teacher self-efficacy as teachers' belief in their ability to influence student learning and achievement, even in challenging circumstances (Bandura, 1997). It reflects teachers' confidence in employing effective strategies, managing classrooms, and motivating students. Teacher self-efficacy is operationalized in this study as a mediating variable linking teacher knowledge, teaching quality, and teaching experience to students' mathematics achievement. Although the Realistic Mathematics Education (RME) approach does not explicitly define self-efficacy, its principles support its development by emphasizing meaningful, context-based learning experiences. For instance, RME's focus on problem-solving, collaboration, and real-world applications enhances teachers' mastery experiences, a key source of self-efficacy (Bandura, 1997; Gravemeijer & Doorman, 1999).

Teacher Knowledge and Mathematics Achievement

Teacher knowledge, which includes both subject matter knowledge and pedagogical content knowledge, is fundamental to effective mathematics instruction (Shulman, 1986). While teachers are recognized as the most crucial factor in students' learning outcomes, the specialized knowledge held by experienced teachers' remains underexplored. Effective teaching is a highly complex cognitive activity that necessitates the application of knowledge across multiple domains. Teachers with well-differentiated and integrated knowledge systems are likely to be more effective than those with limited or fragmented understanding (Thurm, et al., 2024). Teaching involves the systematic transfer of knowledge from teachers to students, encompassing planning, implementation, evaluation, and feedback (Thurm, et al., 2024). Thorough planning is essential for producing effective teaching, which in turn fosters effective learning within the classroom (Affuso et al., 2022). One hallmark of proficient teachers is their possession of substantial pedagogical content knowledge (PCK). According to Grossman (1990), as cited in Thurm, et al. (2024), PCK includes the general knowledge, beliefs, and skills related to teaching that have been a focal point of educational research from the 1960s through the 1980s. Pedagogical content knowledge is a multifaceted concept that involves the ability to convey complex ideas in a manner that students can understand. Teachers' knowledge and reasoning are pivotal in enhancing student learning and achievement. The effectiveness of teaching a particular concept is heavily dependent on the pedagogical strategies employed by the teacher. Akosah et al. (2024) highlight the deficiencies of traditional teaching methods, which contrast with the innovative approaches fostered by strong pedagogical knowledge. Recent research emphasizes the influence of teachers' PCK on student learning and achievement, particularly in science and mathematics education (Baker et al., 2022). Teachers with advanced PCK are better equipped to create learning environments that challenge and support students' learning processes, anticipate difficulties, and adaptively respond to students' needs. Baker et al., (2022) further elaborates that pedagogical knowledge encompasses an awareness of common student misconceptions and the ability to tailor instruction to the appropriate grade levels. In understanding the relationship between teachers' PCK and students' academic achievement, it is important to differentiate between content knowledge (CK) and pedagogical knowledge (PK) before integrating them into the concept of PCK. CK refers to the "what" of teaching, while PK relates to the "how." When these two forms of knowledge are effectively combined, they form a powerful tool for enhancing students' academic performance in mathematics.

Teaching Quality and Mathematics Achievement

Teaching quality, which includes instructional effectiveness, classroom management skills, and the ability to create a positive learning environment, is a significant determinant of student achievement (Williams & Sembiante, 2022). Effective instructional strategies, such as providing relevant examples, scaffolding learning, and employing diverse teaching methods, are hallmarks of quality teachers (Khodarahmi et al., 2022). These practices promote understanding, critical thinking, and problem-solving abilities among students, ultimately leading to improved mathematics achievement. Research by Dupuis et al. (2020) suggests that highly effective teaching leads to both short-term and long-term intellectual gains in students. In every educational context, teaching quality is a critical factor in advancing student achievement and narrowing achievement gaps (Hachfeld & Lazarides, 2021). Teaching quality not only motivates students but also encourages active participation in mathematics lessons, which is crucial for achieving higher grades and understanding the importance of mathematics in other subjects (Affuso et al., 2022). Quality teachers are adept at recognizing the diverse needs and abilities of their students and implementing differentiated instruction accordingly (Amoako et al., 2023).

Teaching Experience and Mathematics Achievement

Teaching experience is another critical factor influencing student achievement. Experienced teachers are generally more proficient in classroom management, delivering effective instruction, and addressing the diverse needs of students (Rice, 2010). Research indicates a positive correlation between teaching experience and student achievement, particularly in mathematics (Atta & Bonyah, 2023). Experienced teachers possess the skills necessary to create a learning environment that fosters deep mathematical understanding and enhances students' problem-solving abilities. Their ability to draw on years of practice enables them to effectively support student learning and adapt to the dynamic needs of their classrooms.

Mediating Role of Teacher Self-Efficacy

Teacher self-efficacy, defined as a teacher's belief in their ability to execute specific pedagogical actions and achieve educational goals, plays a pivotal role in the learning process (Bandura, 1977, as cited in Abdullah & Ahmed, 2022). Self-efficacy is distinct from simply knowing what to do; it involves the confidence to apply one's skills and knowledge effectively in the classroom. Teachers with high self-efficacy are more likely to implement innovative teaching practices, even in challenging environments (Khodarahmi et al., 2022). Numerous studies have demonstrated that teachers with strong self-efficacy beliefs exert greater effort in the classroom, engage more deeply in the teaching-learning process, and are more effective in selecting appropriate methods and techniques (Affuso et al., 2022; Woodcock & Faith, 2021; Akman, 2021). Consequently, such teachers are more successful in implementing curricula and fostering a positive learning environment. Teachers with high self-efficacy are also more enthusiastic, plan more efficiently, and are better equipped to overcome the challenges associated with teaching mathematics.

Conceptual Framework

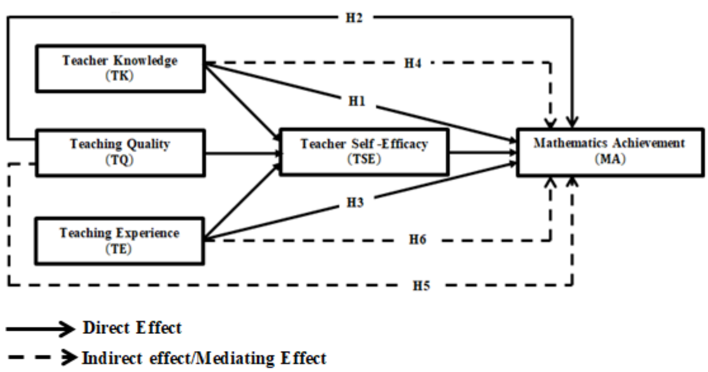


Figure 1
Conceptual framework of the study

The conceptual framework illustrated in the study explores the relationships between teacher variables, teacher self-efficacy, and students' mathematics achievement in Ghanaian junior high schools. It is rooted in Bandura's Social Cognitive Theory (SCT) (Bandura, 1997), which emphasizes the role of self-efficacy beliefs in influencing behavior and outcomes.

The framework posits both direct effects and indirect effects (mediated by teacher self-efficacy) on mathematics achievement:

1. Direct Effects:

H1: *Teacher knowledge has a direct positive effect on JHS students' mathematics achievement.*

H2*:* *Teaching quality has a direct positive effect on JHS students' mathematics achievement.*

H3: *Teaching experience has a direct positive effect on JHS students' mathematics achievement.*

2. Mediated Effects:

H4: *teachers' self - efficacy mediates the relationship between teacher knowledge and JHS students' mathematics achievement.*

H5: *teachers' self - efficacy mediates the relationship between teaching quality and JHS students' mathematics achievement.*

H6: *teachers' self - efficacy mediates the relationship between teaching experience and JHS students' mathematics achievement.*

In this model, teacher self-efficacy serves as the key mediator, reflecting how teachers' beliefs in their capabilities influence their teaching behaviors and, consequently, students' mathematics performance.

RESEARCH METHOD

Research Design and Respondents

This study employed a quantitative research design, specifically utilizing a structural equation model (SEM) to test the research hypotheses. A cross-sectional descriptive correlational design was selected as the most appropriate methodology for examining the relationships between teacher variables—teacher knowledge, teaching quality, teaching experience, and teacher self-efficacy—and students' mathematics achievement in junior high schools across Ghana. The study population comprised all junior high school (JHS) mathematics teachers across the sixteen regions of Ghana and their respective students. However, for practical reasons, the sample was drawn from eight selected regions: Ashanti, Bono East, Central, Eastern, Greater Accra, Northern, Oti, and Volta. The study involved two groups of participants: mathematics teachers and students from junior high schools in Ghana. A total of 507 JHS mathematics teachers and their 5070 students from these regions were selected using a stratified purposive sampling technique. The sample included teachers and students from JHS 1, JHS

2, and JHS 3 levels across the selected schools. Data was collected through the administration of structured questionnaires and RME achievement test, which were distributed to respondents while they were at school. Slovin's method was used to determine the sample size of the teachers, which recommended a minimum sample size of 388. However, to account for potential inaccuracies or incomplete responses and to enhance the study's external validity, the target sample size was increased to 520 junior high school mathematics teachers in Ghana. Given that these teachers were already organized within their respective zones, the sample size within each stratum (region) was determined using a proportionate stratified sampling technique. After excluding invalid data, 507 valid questionnaires were collected, resulting in a response rate of 97.5%. This high response rate was deemed a reliable representation for the study, providing robust insights into the practice of urban mathematics education within Ghana's junior high schools. Additionally, for each of the 507 junior high school teachers, 10 students of theirs were randomly sampled. In all, 5,070 students participated in the study. The demographic characteristics of the study respondents are presented in Table 1.

Table 1
Demographic Characteristics of the Study Group

Variables	**Categories**	**Frequency(n)**	**Percentage (%)**
Gender of Teachers	Male	376	74
	Female	131	26
	Total	**507**	**100**
Gender of Students	Boys	3,892	77
	Girls	1,178	23
	Total	**5070**	**100**
Age of Teachers	< 30	53	10
	$30 - 40$	211	42
	$41 - 45$	103	20
	46 and above	140	28
Years of Teaching Experience of Teachers	$1 - 5$ years	69	14
	$6 - 10$ years	111	22
	> 10 years	327	64
Teachers Highest Qualification	Cert A	105	21
	Diploma	235	46
	Bachelor Degree	162	32
	Masters	5	1

(Source: Field survey, 2024)

Table 1 provides a summary of the demographic characteristics of the study sample, consisting of 507 junior high school mathematics teachers from selected regions in Ghana. The gender distribution indicates that a significant majority of the respondents were male, with 376 participants (74%), compared to 131 females (26%). This suggests a gender imbalance in the teaching profession within the sample, which may reflect broader trends in the teaching workforce in Ghana. Regarding age distribution, the majority of the participants fell within the 30-40 age group, representing 42% (211 participants). The next largest age group was those aged 46 and above, accounting for 28% (140 participants). Teachers aged 41-45 years made up 20% (103 participants), while those less than 30 years constituted the smallest group at 10% (53 participants). This age distribution suggests that the teaching workforce in the sample is predominantly middle-aged, with a substantial proportion of experienced teachers. In terms of teaching experience, the data reveal that a majority of the respondents have significant experience in the field. Teachers with more than 10 years of experience made up 64% (327 participants) of the sample. Those with 6-10 years of experience accounted for 22% (111 participants), while the least experienced group, with 1-5 years of teaching, comprised 14% (69 participants). This indicates a highly experienced cohort, which could positively influence teaching quality and student outcomes. The highest qualifications of the participants show that nearly half of the teachers (46%, 235 participants) held a Diploma, followed by 32% (162 participants) who possessed a Bachelor's degree. A smaller proportion of teachers had a Certificate A qualification (21%, 105 participants), while only 1% (5 participants) had attained a Master's degree. The distribution of qualifications highlights the prevalence of Diploma and Bachelor's degree holders in the teaching workforce, with relatively few teachers holding advanced degrees. In all, 5,070 students participated in the study, the boys were 77% (n=3,892) and the girls were 23% (n=1,178). Out of the 507 mathematics teachers, 162 (77.1%) were male teachers whereas 48 (22.9%) were female teachers.

Instrumentation and Procedures

A structured questionnaire and RME mathematics achievement test were developed by the researchers to serve as the primary data collection instrument for this study. The questionnaire comprised 55 items, systematically organized into six sections: demographic information, teacher knowledge, teaching quality, teaching experience, teacher self-efficacy, and mathematics achievement. The study focused on five key variables: teacher knowledge, teaching quality, teaching experience, teacher self-efficacy, and mathematics achievement. The first four of these variables was measured using a 5-point Likert scale, ranging from 1 (Strongly disagree) to 5 (Strongly agree).

Teacher Knowledge: This variable was assessed through items that gauged respondents' confidence in explaining mathematical concepts, their ability to adapt instructional strategies, and their capacity to integrate interdisciplinary connections into lessons. Sample items included: "I am extremely confident in my ability to explain difficult mathematical concepts to learners in a clear and understandable way," and "I frequently adapt my instructional strategies to meet the diverse learning needs of my learners in mathematics."

Teaching Quality: The measurement items for this variable focused on the quality of teaching practices, particularly in terms of incorporating feedback, staying updated on best practices, and addressing diverse learning styles. For example, respondents were asked to rate statements like "I often incorporate feedback from students to enhance the quality of my teaching" and "I always stay updated on best practices in mathematics education to maintain high teaching quality."

Teaching Experience: Items under this variable evaluated the impact of teaching experience on classroom management, effective teaching practices, and overall student success. Sample items included: "My teaching experience has improved my classroom management skills," and "My teaching experience has contributed to my understanding of effective mathematics teaching practices."

Teacher Self-Efficacy: This variable was assessed through items designed to capture teachers' beliefs and confidence in delivering lessons within the Realistic Mathematics Education (RME) approach. Sample items included: "My self-efficacy impacts my willingness to try innovative teaching methods, including RME, in many ways," and "I feel that my self-efficacy is influenced by the support I receive from colleagues and administrators."

Mathematics Achievement: The measurement of this variable was assessed through a 10-item test, which was designed based on the principles of Realistic Mathematics Education (RME). The test evaluates students' proficiency in fundamental mathematical areas, such as algebra, geometry, and arithmetic. Example items include: “If you have 15 apples and give away 7, how many apples do you have left?” “You are buying 3 T-shirts, each costing ₵12. How much will the total cost be?” and “A garden is shaped like a rectangle. If the length is 10 meters and the width is 5 meters, what is the area of the garden?”. The Students' Mathematics Achievement is represented by the average score of the 10 test items for the students of a specific teacher.

Reliability and Validity of Constructs

To ensure the reliability and validity of the constructs, Cronbach's alpha analysis was performed using SPSS (v.26) to assess the internal consistency of the measurement items of the questionnaire and the achievement test. A Cronbach’s alpha (CA) value of at least .7 was considered acceptable for internal consistency (Pomegbe et al., 2020). As shown in Table 2, the CA values for the variables were as follows: teacher knowledge (.869), teaching quality (.874), teaching experience (.891) and teacher self-efficacy (.931). The RME mathematics achievement test, validated with a Cronbach's alpha of .927, measured student outcomes. Convergent validity was evaluated using average variance extracted (AVE) and composite reliability (CR). According to Fornell and Larcker (1981), an AVE score of .5 and a CR score of .7 are the minimum thresholds for achieving convergent validity. The AVE and CR values reported in Table 2 demonstrate that the constructs met these criteria, with the lowest AVE being .740 (teacher knowledge) and the lowest CR being .892 (teacher self-efficacy).

Table 2
Construct Reliability

Variable	Cronbach alpha (CA)	Composite reliability (CR)	The average variance extracted (AVE)
Teacher Knowledge	.869	.944	.740
Teaching Quality	.874	.962	.809
Teaching Experience	.891	.948	.948
Teacher Self - Efficacy	.931	.892	.797
Mathematics Achievement	.927	.981	.837

Field survey, 2024

This analysis confirms the reliability and validity of the measurement instruments used in the study, ensuring that the constructs accurately capture the intended variables and are consistent across the sample.

Confirmatory Factor Analysis

To assess the reliability and validity of the model, a Confirmatory Factor Analysis (CFA) was conducted using AMOS version 23 software, employing the maximum likelihood estimation method. Measurement items with factor loadings below .5 were excluded from further analysis, following the guidelines suggested by Arthur et al. (2021). Specifically, four measurement items each were removed from the constructs of teacher knowledge and teaching quality, while five items were eliminated from teaching experience. In contrast, the construct of mathematics achievement retained all ten of its measurement items, as they exhibited satisfactory factor loadings. As recommended by Hair et al. (2010), the model fit indices were evaluated against specific thresholds: the CMIN/df ratio should be less than three, Tucker-Lewis Index (TLI) and Comparative Fit Index

(CFI) should exceed 0.9, Goodness-of-Fit Index (GFI) should be greater than 0.8, and both the Root Mean Square Residual (RMR) and Root Mean Square Error of Approximation (RMSEA) should be less than or equal to 0.08. The results, as presented in Table 2, indicate that all the model fit indices met these criteria, confirming that the data set appropriately fits the proposed model. This analysis supports the reliability and validity of the constructs within the study, ensuring that the measurement model is robust and accurately reflects the underlying theoretical framework.

Table 3

Confirmatory Factor Analysis

MFI:CMIN=219.758;df=160;CMIN/df=1.373;GFI=0.949;CFI=0.960;TLI=0.994; RMR=0.063;RMSEA=0.128;P-value=0.060	
Variables	
Teacher Knowledge: CA=.869; CR=.944; & AVE=.740	**Factor Loadings**
TK1: I am extremely confident in my ability to explain difficult mathematical concepts to learners in a clear and understandable way.	.884
TK2: I frequently do adapt my instructional strategies to meet the diverse learning needs of my learners in mathematics	.908
TK3: I consistently assess learners' prior knowledge and use it to inform my instructional decisions.	.916
TK4: I always do integrate interdisciplinary connections into my mathematics lessons based on my content knowledge.	.913
TK5: I consistently use my content knowledge to design challenging and meaningful mathematics tasks for learners.	.889
TK6: I am extremely confident in my ability to solve complex mathematical problems related to the curriculum i teach.	.769
Teaching Quality: CA=.874; CR=.962; & AVE=.809	
TQ1: I do often incorporate feedback from students to enhance the quality of my teaching.	.938
TQ2: I always stay updated on best practices in mathematics education to maintain high teaching quality.	.870
TQ3: I often collaborate with colleagues to share successful teaching strategies and enhance teaching quality.	.910
TQ4: I prioritize student-centered approach in maintaining	.913

the quality of my mathematics instruction.	
TQ5: I address diverse learning styles within my classroom to maintain a high level of teaching quality.	.874
TQ6: I ensure that my teaching methods align with the learning needs and abilities of my students.	.892
Teaching Experience: CA=.891; CR=.948; & AVE=.786	
TE1: My teaching experience has improved my classroom management skills.	.930
TE2: My teaching experience has contributed to my understanding of effective mathematics teaching practices.	.936
TE3: I do often leverage my teaching experience to create a positive and inclusive classroom environment.	.903
TE4: I believe my teaching experience contributes to the overall success of my students in mathematics.	.917
TE5: I balance traditional teaching methods with innovative approaches, considering my teaching experience.	.906
Teacher Self - Efficacy: CA=.913; CR=.922; & AVE=.797	
TSE1: My self-efficacy impacts my willingness to try innovative teaching methods including RME in many ways.	.888
TSE2: I feel that my self-efficacy is influenced by the support I receive from colleagues and administrators.	.944
TSE3: My self-efficacy influences my decision-making in adopting new teaching approaches.	.844
Mathematics Achievement: CA=.927; CR=.981; & AVE=.837	
MA1: Buying 3 T-shirts at ₵12 each (Algebra).	.922
MA2: Calculating the area of a rectangular garden (Geometry).	.931
MA3: Determining apples left after selling some (Arithmetic).	.934
MA4: Calculating months to save for a ₵500 phone (Algebra).	.909
MA5: Finding the perimeter of a wooden frame (Geometry).	.900
MA6: Total cups of drinks needed for 40 guests (Arithmetic).	.920

MA7: Weeks money will last when spending ₵40 weekly (Algebra).	.906
MA8: Area of a rectangular swimming pool (Geometry).	.912
MA9: Gas required for a 200-mile road trip at 20 miles per gallon (Arithmetic).	.891
MA10: Dividing a ₵500 prize among 5 friends (Algebra).	.923

Source: Survey Data, 2024.

The results presented in Table 3 show that the CFA model for the constructs fits the data well. Specifically, the CMIN/df value of 1.373 is well within the acceptable range, indicating a good model fit. The GFI (Goodness-of-Fit Index) is 0.949, TLI (Tucker-Lewis Index) is 0.994, and CFI (Comparative Fit Index) is 0.960, all of which exceed the recommended thresholds, further supporting the model's adequacy. The RMR value of 0.063 and RMSEA of 0.128, although slightly higher than ideal, are still within the permissible range, ensuring that the model is a reasonable representation of the data. The P-value of 0.060 confirms that the model is not significantly different from the observed data, solidifying the model's fitness. Overall, these fit indices suggest that the CFA model adequately captures the relationships among the constructs, making it a reliable foundation for further analysis. CMIN/df (1.373) value indicates a good fit as it is well below the threshold of 3. A lower CMIN/df suggests that the model fits the data with minimal error. Also GFI (0.949) value exceeds the recommended threshold of 0.8, indicating a good overall fit of the model to the data Whiles TLI (0.994) and CFI (0.960) both indices were above the 0.9 threshold, which demonstrates that the model had a good incremental fit compared to a null model, suggesting that the specified model is a significant improvement over an independent model. Moreover, RMR (0.063) and RMSEA (0.128) were within the acceptable range, suggesting that the residuals (differences between observed and predicted covariances) were relatively low. Although the RMSEA is slightly higher than the ideal threshold, it is still within an acceptable range, indicating that the model has a reasonable approximation of the data. Finally, the P-value (0.060) being greater than 0.05 indicates that the model is not significantly different from the observed data, further confirming its appropriateness. These results collectively suggest that the CFA model is a good fit for the data, making it suitable for subsequent analysis and interpretation.

Discriminant Validity

In alignment with previous studies such as Bamfo et al. (2018), this study assessed discriminant validity by comparing the square root of the Average Variance Extracted (√AVE) values with the inter-correlation scores of the constructs. Discriminant validity is achieved when the lowest √AVE value is higher than the highest correlation coefficient (Arthur et al., 2021; Sarsah et al., 2020). According to Table 4, the lowest √AVE value was .860, while the highest correlation coefficient was .072, indicating that discriminant validity was successfully established in this study. This robust discriminant validity suggests that the constructs measured are distinct from one another. Additionally, since the highest correlation coefficient was below .7, multicollinearity was not a concern, ensuring that no confounding effects were introduced into the model estimation process (Dogbe et al., 2020).

Table 4

Discriminant Validity Assessment

Construct Pair	Correlation (r)	AVE	√AVEs
TK		.740	.860
TQ		.809	.899
TE		.786	.886
TSE		.797	.893
MA		.837	.915
TK ↔ MA	.051		
TQ ↔ MA	.049		
TSE ↔ MA	.253		
TE ↔ MA	.072		

Source: Field survey, 2024

Descriptive Analysis

The study analyzed the relationships between teacher-related variables (TK, TQ, TE, and TSE) and students' MA. The means and standard deviations for the latent variables are presented in the table 5 below:

Table 5

Latent Variables, Mean and Standard Deviation

Variable	Mean (M)	Standard Deviation(SD)
Teacher Knowledge	4.50	.35
Teaching Quality	4.55	.40
Teaching Experience	4.60	.38
Teacher Self - Efficacy	4.65	.42
Mathematics Achievement	7.40	.82

Field survey, 2024

From table 5, TK had a mean (M) of 4.50 and a standard deviation (SD) of 0.35. This variable captures teachers' confidence and ability to effectively teach mathematical concepts. The relatively high mean reflects that teachers generally feel well-prepared with the necessary knowledge for mathematics instruction, while the low standard deviation indicates consistent confidence levels across the sample. TQ had a mean of 4.55 and a standard deviation of 0.40. This variable highlights teachers' instructional practices and their ability to address diverse learning needs. The high mean reflects a positive overall perception of teaching quality, whereas the moderate standard deviation points to some variability in how these practices are implemented. TE had a mean of 4.60 and a standard deviation of 0.38. This variable examines the influence of teachers' years of experience on classroom management and student outcomes. The slightly higher mean suggests that teaching experience is generally favorable across the sample, while the moderate standard deviation indicates slight differences in the level of experience among respondents. TSE had a mean of 4.65 and a standard deviation of 0.42. This variable measures teachers' confidence in influencing student outcomes and adopting innovative teaching strategies. The highest mean among all the latent variables suggests strong self-efficacy perceptions among teachers. However, the moderate standard deviation reveals some variability in self-efficacy levels across the sample. Finally, students' MA had a mean of 7.40 and a standard deviation of 0.82. This variable reflects students' mathematics performance. The mean indicates moderate achievement levels overall. However, the relatively higher standard deviation compared to teacher-related variables highlights greater variability in students' performance across the sample, suggesting a wider range of mathematics achievement outcomes.

Ethical Considerations

Ethical approval for this research was granted by the AAMUSTED Institutional Ethics and Research Committee at Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED) on May 9, 2024 (Approval code: AAMUSTED/IERC/2024/004). Informed consent was obtained in writing from the Chairman of the Institutional Ethical Review Committee, the Heads of the Departments of Mathematics Education, and the lecturers and teachers involved. The data collected were secured with password protection to prevent unauthorized access (Tripathy, 2013). Additionally, pseudonyms were used for the schools to maintain confidentiality, ensuring that no specific school was referenced in the analysis. The authors also assured the Ghana Education Service (GES) of the confidentiality of the data used in this paper, and retrospective consent was obtained before the data was utilized (Jol & Stommel, 2016).

RESULTS

The path analysis was conducted using Structural Equation Modeling (SEM) with covariance-based SEM Amos (v.23) software, based on 5000 bootstrap samples with a Bias-Corrected Confidence Interval of 95%. The results as shown in table 5, table 6 and figure 2, indicate the following:

Based on table 5 and figure 2, TK with a mean of 4.50 and a standard deviation of 0.35 positively predicted students' MA with a path coefficient of 0.14, indicating that higher teacher knowledge is associated with improved mathematics performance. TQ having a mean of 4.55 and a standard deviation of 0.40, had a stronger positive effect on MA with a path coefficient of 0.18, highlighting its significant contribution to student performance. TE with a mean of 4.60 and a standard deviation of 0.38, also positively influenced MA with a path coefficient of 0.21, showing the importance of experience in teaching mathematics effectively. TSE, with a mean of 4.65 and a standard deviation of 0.42 positively impacted MA with a path coefficient of 0.09, demonstrating a moderate but meaningful role in enhancing students' mathematics outcomes. The covariance between TK and TQ was 0.22, suggesting a moderate positive relationship between teacher knowledge and teaching quality. The covariance between TQ and TE was higher at 0.33, indicating a strong interconnection between teaching quality and teaching experience. The covariance between TK and TE was 0.11, showing a weaker yet positive relationship between teacher knowledge and teaching experience. All variables were modeled with an error variance of 0.36, ensuring robustness in the predictions. The intercept for the model was 1.74, providing a baseline for interpreting the results. The results emphasize the critical role of teacher knowledge, quality, experience, and self-efficacy in shaping students' mathematical achievement, with teaching experience showing the strongest predictive effect. Also, as shown in table 6:

Teacher knowledge had a positive and statistically significant effect on mathematics achievement ($\beta = 0.194$, $p < 0.001$). Thus, Hypothesis H1, which posited that "Teacher knowledge has a direct positive effect on learners' mathematics achievement," was accepted.

Teaching quality also had a significant positive effect on learners' mathematics achievement, suggesting that improvements in instructional quality could enhance students' mathematics performance by approximately 19.4% ($\beta = 0.194$, $p < 0.001$). Consequently, Hypothesis H2, which stated that "Teaching quality has a direct positive effect on learners' mathematics achievement," was accepted.

Teaching experience had a significant positive impact on learners' mathematics achievement, with the potential to enhance performance by about 25.0% ($\beta = 0.250$, $p < 0.002$). Hypothesis H3, which claimed that "Teaching experience has a direct positive effect on learners' mathematics achievement," was accepted.

The study also controlled for variables such as gender, age, highest qualification, and years of teaching experience. The results for these control variables are as follows:

Gender did not have a statistically significant effect on mathematics achievement (β = 0.040, p = 0.223), indicating that gender is not a significant factor in this context.

Age exhibited a negative but not statistically significant effect on mathematics achievement (β = -0.042, p = 0.102), suggesting minimal impact of age differences among students on their mathematics performance.

Highest qualification also did not significantly affect mathematics achievement (β = -0.029, p = 0.233), implying that factors like teaching quality and experience may have a more significant influence.

Years teaching experience as a control variable showed a significant positive effect on mathematics achievement (β = 0.059, p = 0.004), highlighting the importance of experience in effective teaching practices.

Table 6
Direct Path Estimate

Direct paths	Unstandardized estimate (β)	CR	SE	p-value
Gender → MA	.040	1.218	.061	.223
Age → MA	−.042	−1.634	.026	.102
Qualification → MA	−.029	−1.218	.024	.233
Teaching Experience	.059	.020	2.872	.004
TK → MA	.500	1.093	.183	.001
TQ → MA	.194	3.909	.050	.001
TE→ MA	.25	11.205	.045	.002

Note. Model Fit Indices: *CMIN = 219.758; df = 160; CMIN/df = 1.373; CFI = .960; TLI = .994; RMR = .063; RMSEA = .128; PCLOSE = .060; GFI = .949*

Mediating Effect of Teacher Self-Efficacy

From table 7, to assess the mediating effect of teacher self-efficacy in the relationships between the predictor variables (teacher knowledge, teaching quality, teaching experience) and mathematics achievement, the following steps were taken:

1. **Teacher Knowledge → Teacher Self-Efficacy → Mathematics Achievement**: Teacher knowledge had a positive and statistically significant effect on teacher self-efficacy ($\beta = 0.048$, $p < 0.05$). The indirect effect was also statistically significant (coefficient = 0.010), supporting Hypothesis H4, "Teacher self-efficacy mediates the relationship between teacher knowledge and learners' mathematics achievement."
2. **Teaching Quality → Teacher Self-Efficacy → Mathematics Achievement**: Teaching quality significantly influenced teacher self-efficacy ($\beta = 0.030$, $p < 0.05$). The indirect effect was significant, confirming Hypothesis H5, "Teacher self-efficacy mediates the relationship between teaching quality and learners' mathematics achievement."
3. **Teaching Experience → Teacher Self-Efficacy → Mathematics Achievement**: Teaching experience had a significant positive impact on teacher self-efficacy ($\beta = 0.421$, $p < 0.01$), which in turn positively affected mathematics achievement ($\beta = 0.210$, $p < 0.01$). The significant indirect effect (coefficient = 0.003) suggested a partial mediation, validating Hypothesis H6, "Teacher self-efficacy mediates the relationship between teaching experience and learners' mathematics achievement."

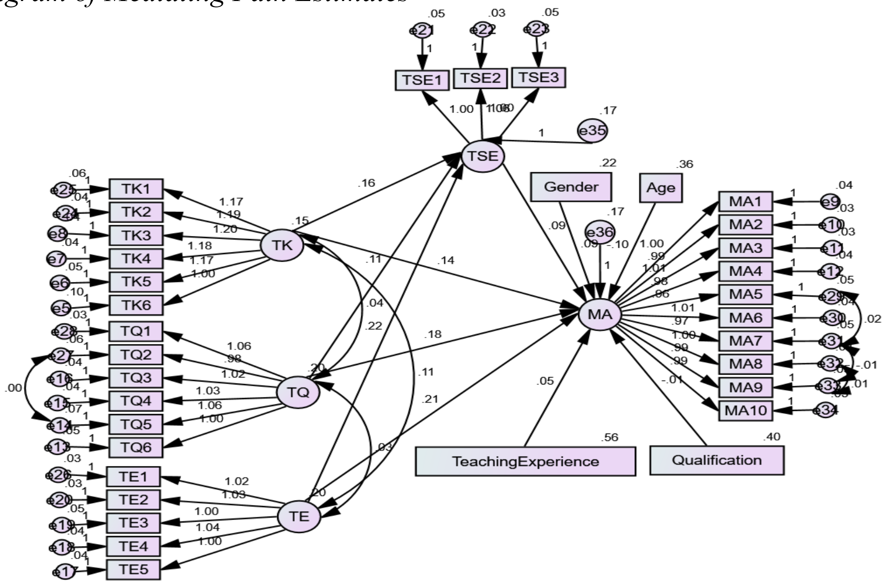
Table 7

Mediating Path Estimates

Mediating Path	Estimate (β)	Standard Error	Lower bias - corrected	Upper bias - corrected	P – value
TK→TSE → MA	.048	.014	.02	.047	<.01
TQ → TSE → MA	.030	.015	.022	.084	<.01
TE → TSE → MA	.210	.017	.024	.091	<.01

Bias – corrected (BC) Percentile Method; 5000 Bootstrap sample; 95% confidence level, P-value significant at 1% (0.01).

Figure 2
Diagram of Mediating Path Estimates



DISCUSSION AND CONCLUSIONS

The primary aim of this research was to examine the relationships between teacher knowledge, teaching quality, teaching experience, and learners' mathematics achievement, while also exploring the mediating role of teacher self-efficacy. The findings of this study underscore the significant contributions of teacher knowledge, teaching quality, and teaching experience to learners' mathematics achievement. Furthermore, the mediating role of teacher self-efficacy was found to be crucial in enhancing these relationships.

First, the study found that teacher knowledge had a significant positive effect on learners' mathematics achievement, a finding that aligns with the work of Dupuis et al. (2020) who emphasized that teachers' deep understanding of subject matter is fundamental to effective teaching and improved student outcomes. Similarly, Hachfeld & Lazarides (2021) highlight the critical role that teacher knowledge plays in delivering effective instruction and fostering student understanding. When teachers possess a deep understanding of the subject matter, they are better equipped to explain complex concepts and tailor their teaching strategies to meet the diverse needs of their students. This result is consistent with recent studies by Shulman (1986) and Atta and Bonyah (2023), who argued that a well-grounded knowledge base enables teachers to deliver more effective and contextually appropriate instruction. The current study contributes to the literature by confirming that in the context of Ghanaian junior high schools, teacher knowledge remains a pivotal factor in fostering students' academic success in mathematics.

Secondly, teaching quality also demonstrated a significant positive impact on mathematics achievement, reinforcing the findings of Affuso et al. (2022) and Darling-Hammond (2017), who highlighted the importance of high-quality instruction in driving student achievement. Teaching quality, characterized by clarity, engagement, and the ability to adapt to students' needs, has been shown to directly influence learning outcomes (Coe et al., 2014). This study supports the notion that when teachers deliver high-quality instruction, students are more likely to achieve higher levels of academic success. Additionally, the mediating role of teacher self-efficacy in this relationship suggests that teachers who are confident in their abilities to manage classrooms and facilitate learning are more likely to provide high-quality instruction, leading to improved student outcomes. The current study adds to this body of knowledge by confirming that in Ghana, teaching quality is a critical determinant of mathematics achievement, further emphasizing the need for continuous professional development to enhance instructional practices.

Thirdly, teaching experience was found to significantly contribute to learners' mathematics achievement. This finding corroborates the conclusions of studies by Arthur et al. (2022) and Kini and Podolsky (2016), which suggest that experienced teachers are more likely to employ effective teaching strategies and manage classrooms more efficiently, leading to better student outcomes. However, unlike some studies that found diminishing returns to teaching experience after a certain point (Rice, 2010), this study indicates that even incremental increases in experience can yield positive effects on student achievement in the Ghanaian context. The partial mediation by teacher self-efficacy in this relationship indicates that while experience itself is valuable, its impact is amplified when teachers feel confident in their teaching abilities. This underscores the importance of professional development and support systems that enhance teacher self-efficacy, particularly for less experienced teachers.

The study's unique contribution lies in the exploration of teacher self-efficacy as a mediating variable. The results revealed that teacher self-efficacy partially mediated the relationships between teacher knowledge, teaching quality, teaching experience, and learners' mathematics achievement. This finding aligns with Bandura's (1997) Social Cognitive Theory, which posits that individuals' beliefs in their capabilities can significantly influence their actions and outcomes. In education, teacher self-efficacy has been linked to higher levels of instructional creativity, persistence in the face of challenges, and ultimately, improved student performance (Tschannen-Moran & Woolfolk Hoy, 2001). The mediation effect found in this study supports these assertions and highlights the importance of fostering self-efficacy among teachers to enhance educational outcomes.

In comparing these findings with previous research, this study concurs with the general consensus that teacher characteristics significantly influence student achievement. However, it extends the literature by emphasizing the mediating role of teacher self-efficacy, a variable that has not been extensively studied in the Ghanaian context. While previous studies have often focused on direct effects, this study's inclusion of mediation analysis offers a more nuanced understanding of how teacher characteristics interact to influence student outcomes.

IMPLICATIONS

This study has demonstrated that teacher knowledge, teaching quality, and teaching experience are crucial determinants of learners' mathematics achievement in Ghanaian junior high schools. Additionally, the findings underscore the critical role of teacher self-efficacy as a mediating factor in these relationships. These results suggest that interventions aimed at improving mathematics achievement should not only focus on enhancing teachers' knowledge and skills but also on building their self-efficacy.

The major conclusions of this research can be summarized as follows:

1. **Teacher knowledge** is a foundational element that significantly impacts students' mathematics achievement. Therefore, efforts to improve teacher preparation programs and ongoing professional development should prioritize deepening teachers' subject matter knowledge.
2. **Teaching quality** is essential for student success in mathematics, emphasizing the need for professional development programs that enhance teachers' instructional strategies and classroom management skills.
3. **Teaching experience** remains a valuable asset in improving students' academic outcomes, suggesting that retaining experienced teachers and supporting them throughout their careers is crucial.
4. **Teacher self-efficacy** plays a mediating role in the relationship between teacher characteristics and student achievement, highlighting the importance of fostering a positive self-belief among teachers to maximize their effectiveness.

Overall, this study provides valuable insights into the complex interplay between teacher characteristics and student outcomes in the context of Ghanaian junior high schools. The findings suggest that improving mathematics achievement requires a holistic approach that considers not only teachers' knowledge and skills but also their self-efficacy. Future research should continue to explore these relationships in different contexts and with larger samples to validate and extend these findings.

This study is based on a part of the doctoral thesis entitled “Unveiling the Nexus: Realistic Mathematics Education and Teacher Variables Impact on Ghanaian Junior High School Learners’ Mathematics Achievement via Structural Equation Modeling.” 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 the JHS teachers who contributed during the data collection for a successful completion of this research article.

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Ernest F. Akosah, is a PhD Candidate in the Department of Mathematics Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Ghana. His major research interests include realistic mathematics education, ethnomathematics, social justice, and STEM education. Email: akferst@gmail.com

Yarhands D. 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 History of mathematics, STEM education, realistic mathematics education, and problem - solving. Email: ydarthur@aamusted.edu.gh

Benjamin A. Obeng, 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 History of mathematics, STEM education, realistic mathematics education, and problem - solving. Email: baduobeng@aamusted.edu.gh