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Research Article

Unlocking the nexus: Teacher variables effect on learners' mathematics achievement via structural equation modeling

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This study examines the impact of teacher variables—teacher knowledge, teaching quality, and teaching experience—on learners' mathematics achievement through the implementation of realistic mathematics education [RME] in Ghanaian junior high schools. Using a cross-sectional descriptive correlational design, data were collected via structured questionnaires administered to a stratified purposive sample of 507 participants. The questionnaires were designed to capture comprehensive data on teacher variables and learners' mathematics achievement. Structural Equation Modeling assessed the hypothesized relationships. Results indicate significant positive effects of teacher knowledge, teaching quality, and teaching experience on mathematics achievement. The implementation of RME enhanced both learners' mathematics achievement and teachers' self-efficacy in mathematics. Teachers' self-efficacy mediated the relationship between RME implementation and mathematics achievement, as well as between teacher knowledge and mathematics achievement. These findings underscore the importance of teacher variables in improving mathematics achievement through RME, advocating for targeted professional development and curriculum design.

Keywords: Realistic mathematics education, teacher knowledge, teaching quality, teaching experience, mathematics achievement, teacher self-efficacy, structural equation modeling

1. Introduction

Mathematics education plays a crucial role in the development of a nation, forming the backbone of scientific and technological advancements. It has been identified as a tool for national deployment worldwide, hence its incorporation as a core curriculum in most countries around the World (Japelj Pavesic et al., 2022). According to the Organisation for Economic Co-operation and Development [OECD] (2015), strong mathematics education is essential for fostering innovation and economic growth. Similarly, the National Council of Teachers of Mathematics [NCTM] (2018) emphasizes the importance of high-quality mathematics instruction in preparing students for a rapidly changing world. The Programme for International Student Assessment [PISA] consistently highlights the critical role of mathematics literacy in equipping learners with problem-solving skills necessary for their future careers (OECD, 2018). Furthermore, the Trends in International Mathematics and Science Study [TIMSS] (2019) reports that nations with high-performing students in mathematics tend to have well-developed educational policies and practices. Despite these global recognitions, there remains a persistent problem of poor performance in mathematics among learners. The Programme for International Student Assessment consistently highlights significant gaps in mathematics literacy and problem-solving skills among learners from various countries, indicating a need for substantial improvement in mathematics education (OECD, 2018). Additionally, the Trends in International Mathematics and Science Study 2019 report reveals that a considerable number of students worldwide are performing below the expected proficiency levels in mathematics. This underperformance is particularly pronounced in developing countries, where educational resources and teacher training programs are often inadequate (TIMSS, 2019). Due to the capacity of mathematics education to provide peace and security, teaching the subject has become a global concern (Akkus, 2016; Olawale et al., 2021).

In Ghana, as in many other nations, mathematics has been made a compulsory subject for students regardless of their major or specialization, yet students continue to struggle with the subject. This struggle is reflected in national assessments and international benchmarks, where Ghanaian learners frequently score below average in mathematics (TIMSS, 2019). The persistent underachievement in mathematics not only hampers individual learners' academic and career prospects but also poses a threat to the country's overall socio-economic development (OECD, 2015). Improving mathematics achievement at the junior high school level has been a significant concern in Ghana. For example, learners who complete basic education in Ghana sit for a nationwide examination called Basic Education Certificate Examination [BECE] (Quansah et al., 2020). The basic education certificate is awarded to learners who successfully pass the BECE after completion of the nine-year basic education programme. Candidates are graded based on their achievement in the external examination (70%) and school-based (internal) assessment (30%) marks provided by the schools. A nine - point scale (stanine in reversed form) is used in grading the candidates, with Grade 1 denoting the best achievement and Grade 9, the poorest. Mathematics has been one of the worst performed subjects during BECE (Abreh et al., 2018). According to available records from 2013 to 2023, over 3,669,138 BECE candidates who sat for the examination, 1,562,270 (43%) of them failed in mathematics to progress to any secondary, technical or vocational school (GES, 2023). The results show that more than 50% of the learners had grades from grade 7 – 9, apart from 2019 where grades 7 – 9 was a little over 44%. For the years 2015 and 2018, more than half of the learners who took the mathematics examination failed, and 40.3% failed in 2019. According to Ansah (2017), a total of 36,849 candidates (8%) across the country were not placed into senior high school [SHS] because they scored Grade 9 in either English or Mathematics or both. Recent educational reforms have emphasized the need for innovative teaching approaches to enhance student learning outcomes. One such approach is RME, which focuses on connecting mathematical concepts to real-world contexts, thus making learning more meaningful and engaging for students (Van den Heuvel-Panhuizen, 2003).

The effectiveness of RME has been supported by numerous studies indicating its potential to improve students' problem-solving skills and conceptual understanding (Gravemeijer & Cobb, 2017). However, the successful implementation of RME heavily depends on several teacher-related factors, including teacher knowledge, teaching quality, and teaching experience. Teachers play a pivotal role in shaping the learning environment and their ability to effectively implement RME can significantly influence students' mathematics achievement. Additionally, teacher self-efficacy, defined as teachers' beliefs in their ability to influence student outcomes, is crucial in determining their instructional practices and effectiveness (Bandura, 1977; Tschannen-Moran & Woolfolk Hoy, 2017). Teacher factors play a pivotal role in shaping the educational environment and determining the effectiveness of instruction. Arthur et al. (2017) discovered that students' mathematical achievement was influence by the quality of the teacher, the motivation of the teacher and the students, the effectiveness of the instruction, and the teacher's own efficacy. According to studies by Chand et al. (2021), and Hossain and Rezal (2018), factors that influence students' mathematics proficiency include teacher attitude, teacher quality, cooperative learning, motivation, self-efficacy, and teacher-student relationships.

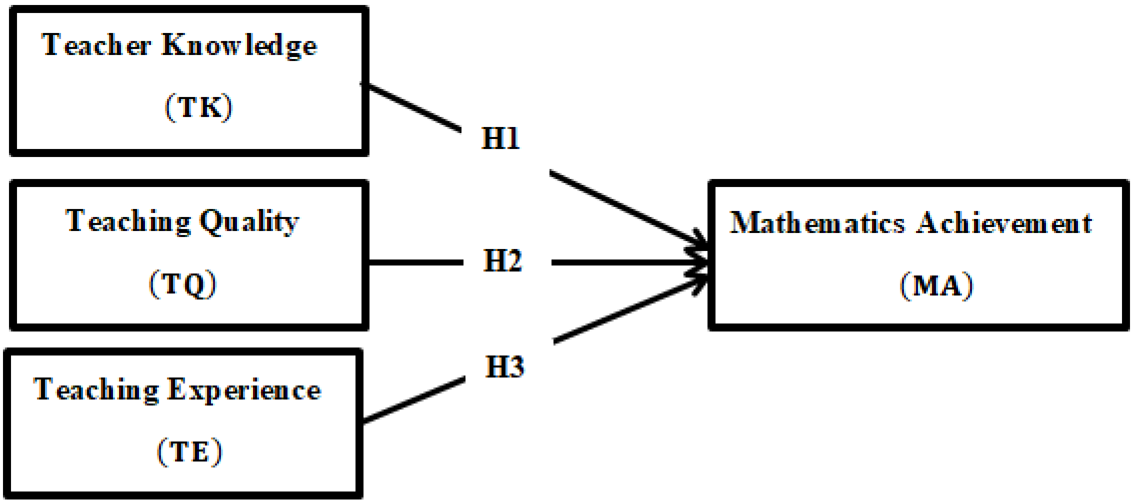
Given the critical role of teachers in the successful implementation of RME, this study aims to investigate the impact of teacher knowledge, teaching quality, and teaching experience on learners' mathematics achievement through the lens of RME. By understanding these dynamics, the study seeks to provide insights into how teacher-related factors can be leveraged to enhance mathematics education in Ghana. The focus on RME is particularly relevant in the context of Ghana's educational reforms, which aim to improve the quality of mathematics education and ultimately, student outcomes. By grounding mathematics learning in real-world contexts, RME can potentially address issues related to student disengagement and poor performance in mathematics. However, for RME to be effective, teachers need to possess adequate knowledge, deliver high-quality instruction, and have substantial teaching experience. Moreover, their self-efficacy plays a critical role in their ability to implement RME effectively.

1.1. The Aim

Despite the recognized importance of teacher variables in educational outcomes, there is a lack of comprehensive research exploring the interplay between these variables and their collective impact on mathematics achievement within the framework of RME, particularly in the Ghanaian context. Most existing studies have focused on isolated aspects of teacher characteristics or have been conducted in different educational contexts, leaving a gap in understanding how these variables interact in the specific setting of Ghanaian junior high schools. Furthermore, while RME has been shown to be effective in various educational settings, its implementation in Ghana is still relatively new and under-researched. There is a need to examine how teacher knowledge, teaching quality, and teaching experience influence the successful adoption of RME and how these factors, in turn, impact student achievement. Therefore, this study seeks to address these gaps by examining the direct effects of teacher knowledge, teaching quality, and teaching experience on learners' mathematics achievement through the implementation of RME. By doing so, the study aims to provide a comprehensive understanding of the factors that contribute to effective mathematics education in Ghana and offer practical recommendations for policy and practice.

A conceptual framework in research is a theoretical structure that lists the main ideas, variables, connections, and presumptions that guide a study. In addition, researchers can use the conceptual framework as a guide to help with study design, hypothesis development, and result interpretation. Figure 1 shows the relationships between the variables.

Figure 1
Conceptual framework of the study



Source: Self-constructed (2024).

In this study, the dependent variable is mathematics achievement, and the independent variables are teacher knowledge, teaching quality, and teaching experience. According to this study, mathematics achievement is directly impacted by teacher knowledge, teaching quality, and students' enthusiasm in mathematics. That is, based on factors like teacher knowledge, teaching quality, and teaching experience, mathematics achievement is likely to differ. The current study examines the effect of teacher knowledge, teaching quality and teaching experience on mathematics achievement through the implementation of RME. The objectives that underpin the investigation are as follows:

a) To determine the effect of teacher knowledge on mathematics achievement through the implementation of RME.

b) To determine the effect of teaching quality on mathematics achievement through the implementation of RME.

c) To determine the effect of teaching experience on mathematics achievement through the implementation of RME.

2. Literature Review

The study sought to examine the effect of teacher knowledge, teaching quality and teaching experience on mathematics achievement among JHS learners through the implementation of RME, using structural equation modeling [SEM]. Before the development of the hypotheses of the study, this section sought to present an empirical review on the effect of teacher variables on students' mathematics achievement.

Teacher knowledge is often considered a critical factor influencing student achievement in mathematics. Teacher knowledge encompasses both subject matter knowledge and pedagogical content knowledge (Shulman, 1986). Research has consistently shown that teachers who possess strong mathematical content knowledge and effective pedagogical skills are more successful in promoting student learning and achievement in mathematics. A study by Hill et al. (2005) found that teachers' mathematical knowledge for teaching is significantly related to student achievement gains in elementary mathematics. Their study, which included a sample of over 700 teachers and 3,000 students, demonstrated that students taught by teachers with higher mathematical knowledge for teaching scored higher on standardized mathematics tests. This underscores the importance of ensuring that teachers possess a deep understanding of both mathematical content and pedagogy to effectively teach mathematics. Similarly, the research by Baumert et al. (2010) in Germany highlighted the impact of teachers' content knowledge and pedagogical content knowledge on student achievement in mathematics. Their findings suggested that both types of knowledge are crucial for effective mathematics instruction and that teachers with higher levels of these knowledge types are better able to support student learning.

Teaching quality, which encompasses the effectiveness of instructional practices, classroom management skills, and the ability to foster a positive learning environment, has been widely recognized as a significant determinant of student achievement. Effective teaching quality involves not only a strong understanding of subject matter but also the ability to deliver instruction in a way that engages students and promotes deep understanding. Lazarides and Buchholz (2019) also assessed how student-perceived teaching quality was related to different achievement emotions in mathematics classrooms. Their study pointed out that teacher support and classroom management was related negatively to class-level boredom; teacher support was positively related to class-level enjoyment; while teacher support reduced student-level mathematics anxiety and boredom. Fauth et al. (2019) looked at the effects of teacher competence on student outcomes in elementary science education, the mediating role of teaching quality. Results demonstrated that pedagogical content knowledge, self-efficacy and teaching enthusiasm were positively related to students' interest; self-efficacy was positively related to student achievement, and teaching quality in the classroom mediated these relationships. Leon et al. (2017) also assessed teaching quality in math class, the development of a scale and the analysis of its relationship with engagement and achievement. Their findings revealed that teaching quality was a predictor of behavioral engagement, and higher grades were observed in classes where students, as a whole, displayed more behavioral engagement.

Teaching experience is another important factor that influences student achievement. Experienced teachers are generally more effective in delivering instruction, managing classrooms, and addressing diverse student needs compared to their less experienced counterparts. Research indicates that teaching experience positively correlates with student achievement, particularly in the early years of a teacher's career (Rice, 2010). A meta-analysis by Kini and Podolsky (2016) reviewed over 30 studies and found that teachers' effectiveness increases significantly with experience, particularly during the first few years of teaching. Their analysis indicated that students taught by more experienced teachers achieve higher academic outcomes, including in mathematics. This supports the idea that investing in teacher retention and development can lead to improved student performance. Moreover, Papay and Kraft (2015) examined longitudinal data to understand the impact of teaching experience on student achievement. They found that teacher effectiveness continues to grow significantly beyond the initial years of teaching, highlighting the importance of continuous professional development and support for experienced teachers.

Overall, the empirical evidence strongly supports the critical role of teacher knowledge, teaching quality, and teaching experience in influencing student achievement in mathematics. Teachers with robust content and pedagogical knowledge, high-quality instructional practices, and significant teaching experience are better equipped to promote student learning and achievement in mathematics.

3. Hypotheses Development

3.1. Teacher Knowledge and Mathematics Achievement

Teacher knowledge, encompassing both subject matter knowledge and pedagogical content knowledge, is crucial for effective mathematics instruction (Shulman, 1986). RME, which emphasizes context-based learning and student engagement with real-world problems, requires teachers to have a deep understanding of mathematical concepts and the ability to connect these concepts to practical situations (Treffers, 1987). Research has shown that teachers with strong mathematical knowledge are better able to implement RME strategies effectively, thereby enhancing student understanding and achievement (Hill et al., 2005). Teachers' content knowledge enables them to design and deliver lessons that are both challenging and accessible, fostering a deeper comprehension of mathematics among students (Baumert et al., 2010). Thus, the first hypothesis is formulated as follows:

H1: Teacher knowledge has a direct positive effect on mathematics achievement through the implementation of RME.

3.2. 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 (Darling-Hammond, 2000). Effective instructional strategies include providing relevant examples, scaffolding learning, and employment by quality teachers (Onyishi & Sefotho, 2020). These instructional practices promote understanding, critical thinking, and problem-solving abilities among students, ultimately leading to improved mathematics achievements. Recognizing the diverse needs and abilities of their students, quality teachers implement differentiated instruction in mathematics classrooms (Guo & Leung, 2021). In the context of RME, teaching quality involves the ability to engage students in meaningful mathematical activities, encourage problem-solving, and support collaborative learning (Gravemeijer, 1994). Effective teaching in RME requires teachers to facilitate student-centered learning experiences that connect mathematical concepts to students' everyday lives. Studies have demonstrated that high-quality teaching practices are associated with improved student outcomes in mathematics (Rivkin et al., 2005; Stronge et al., 2011). Therefore, the second hypothesis is proposed as:

H2: Teaching quality has a direct positive effect on mathematics achievement through the implementation of RME.

3.3. Teaching Experience and Mathematics Achievement

Teaching experience is another critical factor influencing student achievement. Experienced teachers are typically more adept at managing classrooms, delivering effective instruction, and addressing diverse student needs (Rice, 2010). In the RME framework, experienced teachers are more likely to successfully implement context-based learning activities and facilitate student engagement with real-world mathematical problems (Gravemeijer, 1994). Research indicates that teaching experience is positively correlated with student achievement, particularly in mathematics (Kini & Podolsky, 2016). Experienced teachers are better equipped to create a learning environment that promotes deep mathematical understanding and problem-solving skills. Consequently, the third hypothesis is formulated as follows:

H3: Teaching experience has a direct positive effect on mathematics achievement through the implementation of RME.

4. Method

4.1. Research Design

This study used a cross-sectional descriptive correlational design to investigate the impact of teacher variables—teacher knowledge, teaching quality, and teaching experience—on learners' mathematics achievement through the implementation of RME in Ghanaian junior high schools. Firstly, according to Creswell (2014), a cross-sectional design allows researchers to collect data from a large population at a single point in time, making it efficient and cost-effective. Secondly, a descriptive correlational design is ideal for identifying and examining relationships between variables without manipulating the study environment (Creswell, 2014). By using this design, we can observe and describe the natural relationships between teacher knowledge, teaching quality, teaching experience, and learner achievement in a real-world educational setting. Furthermore, this design enables the assessment of multiple variables simultaneously, providing a comprehensive understanding of how different teacher variables collectively influence mathematics achievement (Fraenkel et al., 2019). The use of Structural Equation Modeling (SEM) within this design allows for the testing of complex hypothesized relationships and the exploration of mediating effects, such as teachers' self-efficacy in mathematics. Hence, this design was preferred for the study due to its efficiency, ethical considerations, and ability to provide a detailed understanding of the relationships between teacher variables and learners' outcomes in a natural educational setting. Again, this design aligns with the objectives of the study and supports the robust analysis of data to inform educational practice and policy.

4.2. Participants

The study gathered data from five hundred and seven (507) junior high school mathematics teachers, selected from a population of twelve thousand nine hundred and eighty (12,980) teachers across eight regions in Ghana (Ashanti, Bono East, Central, Eastern, Greater Accra, Northern, Oti, and Volta Regions). These regions were chosen to provide a diverse representation of educational settings in the country. The participants were selected using a stratified purposive sampling technique to ensure that a comprehensive and representative sample of teachers with varying levels of knowledge, experience, and teaching quality was included. Teachers were chosen based on their active role in implementing the RME approach, which is integral to the study's focus on examining the impact of teacher variables on learners' mathematics achievement. The selection criteria ensured that the teachers were familiar with the RME methodology, thereby allowing for a more accurate assessment of the relationships between teacher variables and student outcomes.

4.3. Instruments

The study utilized a structured questionnaire as the primary measurement tool to gather data on teacher variables and learners' mathematics achievement. The preference for a structured questionnaire was based on its highly efficient for collecting data from large samples, which was crucial given the study's sample size of 507 junior high school mathematics teachers (Creswell, 2014). It also allows for the standardized collection of data, ensuring consistency and comparability across respondents. According to Cohen et al., (2018) the predefined questions and response options enable researchers to quantify responses and perform complex analyses, such as Structural Equation Modeling, to test hypothesized relationships. This adaptability is particularly beneficial in reaching participants across multiple regions (Bryman, 2016), as in this study.

The study focused on teacher variables and mathematics study achievement, but the teacher variables had three dimensions (based on our theoretical model). There were therefore three independent variables (teacher knowledge – TK, teaching quality – TQ, and teaching experience – TE) and one dependent variable (mathematics achievement – MA). These four (4) variables were all measured on a Likert scale weighted 1 (Strongly Disagree) to 5 (Strongly Agree). The teaching quality, teaching experience, teacher knowledge and mathematics achievement all had ten measurement items each. The study also controlled for teachers' age, gender, qualification and years of teaching experience.

4.4.1. Reliability and validity of the constructs

According to Creswell (2014), a measure's validity refers to how effectively it captures the notion being studied, and this is done by a panel's or judge's decision. The term "reliability" describes how well a measurement yields consistent results across time and even when it is applied by different researchers. The questionnaire's internal consistency was assessed using Cronbach's alpha [CA] reliability testing after a pilot test to guarantee reliability. If a Cronbach's alpha score is at least .7, it is considered that internal reliability or consistency has been attained (Pomegbe et al., 2020). As demonstrated in Table 1, teacher knowledge [TK] had a CA of .869, indicating a high level of internal consistency reliability, Teacher quality [TQ] had a CA of .874, showing good internal consistency, and teaching experience [TE] had a CA of .891. Finally, mathematics achievement [MA] had a CA of .927 indicating good internal consistency. Additionally, the analysis of the table 3 demonstrates that convergent validity is well-established for all constructs (TK, TQ, TE, and MA) based on the criteria recommended by Hair et al. (2010). Specifically: composite Reliability [CR]: all values were significantly above the .7 threshold. And Average Variance Extracted [AVE]: all values exceed the .5 threshold. According Fornell and Larcker (1981), convergent validity is said to be achieved when the construct scores AVE greater than .5. All composite reliability values were greater than .7, indicating that the constructs have good internal consistency and reliability. This means that the items used to measure each construct are highly correlated with each other. All AVE values are greater than .5, which suggests that more than 50% of the variance in the items is captured by the construct. This indicates a good level of convergent validity, meaning the items adequately represent the underlying construct. Hence, the constructs used in your study are reliable and valid, indicating that the measurement model is sound. Given that both Cronbach's alpha and the composite reliability score are higher than the generally accepted criterion of .70 for reliability, these values suggest that the latent variables in the model have internal consistency reliability ranging from good to outstanding.

Table 1
Construct Reliability

Convergent Validity	*TK*	*TQ*	*TE*	*MA*
CA ($value > .7$)	.869	.874	.891	.927
CR ($value > .7$)	.944	.962	.948	.981
AVE ($Value > .5$)	.740	.809	.786	.837
Convergent Validity	Established	Established	Established	Established

4.4.2. Confirmatory Factor Analysis [CFA]

As part of the reliability and validity checks, the study run a confirmatory factor analysis in Amos (v.23), using maximum likelihood (results presented in Table 5). The CFA assessed how well the data fits our model for the study. The measurement items with poor factor loadings (less than 0.5) were deleted from further analysis. Four (4) measurement items each were deleted from teacher knowledge and teaching quality, while five measurement items was deleted from teaching experience. Mathematics achievement had all its ten measurement items properly fitting, so none was deleted.

4.4.3. Model fit

Another important consideration when CFA is run is the fitness of the model estimated. As part of the fitness checks, CMIN/DF is supposed to be less than 3, CFI is all expected to be greater than .9, RMSEA and RMR are also expected to be less than 0.08, while P-Close is also expected to be statistically insignificant at 5% (greater than .05) (Hair et al., 2010). The results presented in Table 2 indicate that the CFA model for the constructs appropriately fits the data. Figure 2 presents the CFA in a diagrammatic form.

Table 2
Confirmatory Factor Analysis

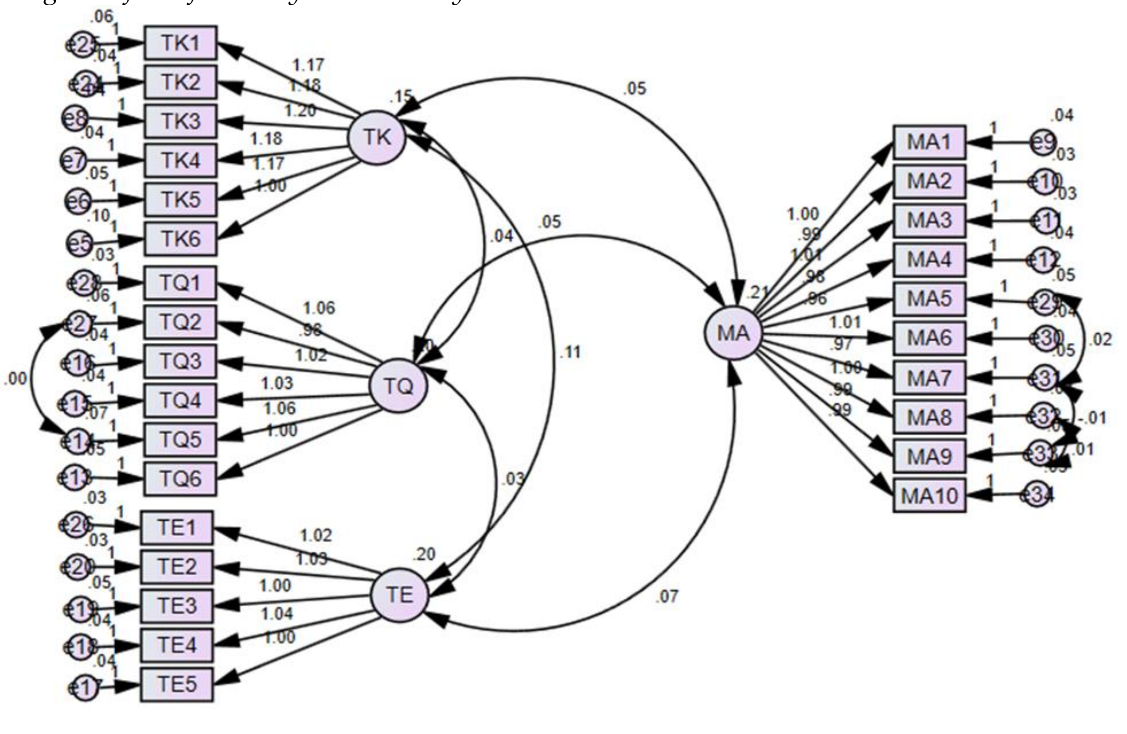
Fit Indices: CMIN = 219.758; df = 160; CMIN/df =1.373; CFI =.960; TLI = .994; RMR = .063; RMSEA = .128; PCLOSE = .000; GFI = .949

Variable	
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 the quality of my mathematics instruction.	.913
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

Table 2 continued

Mathematics Achievement: CA=.927; CR=.981; & AVE=.837	**Factor Loadings**
MA1: I believe my self-efficacy influences students' mathematics achievement in my class.	.922
MA2: I think my teaching methods contribute to students' understanding of realistic mathematics concepts.	.931
MA3: Per my experience, self-efficacy played a role in mediating the relationship between realistic mathematics education and students' mathematics achievement.	.934
MA4: I employ realistic mathematics education strategy to support students in overcoming challenges in mathematics learning.	.909
MA5: Am aware of the impact of my self-efficacy on the overall quality of my teaching and its potential mediation effect on students' achievement.	.900
MA6: My teaching experience makes my student get good marks in mathematics.	.920
MA7: My students usually do well in mathematics.	.906
MA8: Realistic mathematics education helps my students to understand mathematics and other subjects.	.912
MA9: My students feel happy when answering mathematics questions.	.891
MA10: I often foster a growth mindset among my students, and this usually impact the mediation of self-efficacy in mathematics achievement.	.923

Figure 2
Diagram of Confirmatory Factor Analysis



4.4.4. Discriminant validity

As presented in past studies such as Bamfo et al. (2018), this study assessed discriminant validity by comparing the square of the AVEs with the inter-correlation scores. To achieve discriminant validity, the squared AVEs were supposed to be greater than the squared inter-correlation scores, and this was achieved by this study (Table 3). The least AVE recorded was .740 (teacher knowledge), while the highest correlation score was .072 (between mathematics achievement and teaching experience). Another issue worth considering is multicollinearity, that is, the level of correlation among the independent variables. Although some level of correlation is expected between the independent variables, this is not supposed to be high (.8 and above). The highest correlation in this study was .072, which was less than .8, and so we conclude that there was no issue of multicollinearity in this study.

Table 3
Discriminant Validity Assessment

Construct Pair	*Correlation* (r)	*Squared Correlation* (r^2)	*AVE1*	*AVE2*
TK ↔ MA	.051	.0002	.740	.837
TQ ↔ MA	.049	.0024	.809	.837
TE ↔ MA	.072	.0051	.786	.837

5. Results

The research hypothesis tested the effects of teacher knowledge, teaching quality, and teaching experience on mathematics achievement through the implementation of RME. Structural Equation Modeling was used to evaluate these relationships. The analysis also controlled for gender, age, highest qualification, and years of teaching experience of the respondents. The findings are summarized in Table 4.

Table 4
Direct Path Estimate

Direct paths	*Unstandardized estimate* (β)	*CR*	*SE*	*p*
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 = .000; GFI = .949.

5.1. Interpretation of Results

5.1.1. Hypothesis H1: Teachers' Knowledge

The hypothesis that teachers' knowledge has a direct positive effect on mathematics achievement through the implementation of RME was accepted. The unstandardized estimate (β = .500, p <.001) indicates a strong positive relationship. This suggests that enhanced teacher knowledge significantly improves students' mathematics achievement, supporting the notion that well-informed teachers can effectively implement RME strategies to benefit student learning.

5.1.2. Hypothesis H2: Teaching Quality

The hypothesis that teaching quality has a direct positive effect on mathematics achievement through the implementation of RME was also accepted. The unstandardized estimate (β = .194, p <.001) signifies a meaningful positive impact. This result aligns with existing literature suggesting that high teaching quality, characterized by effective instructional strategies and classroom management, contributes to better student outcomes in mathematics.

5.1.3. Hypothesis H3: Teaching Experience

The hypothesis that teaching experience has a direct positive effect on mathematics achievement through the implementation of RME was accepted. The unstandardized estimate (β = .250, p <.002) shows a significant positive relationship. Experienced teachers are likely more adept at applying RME methodologies, thereby enhancing student performance in mathematics.

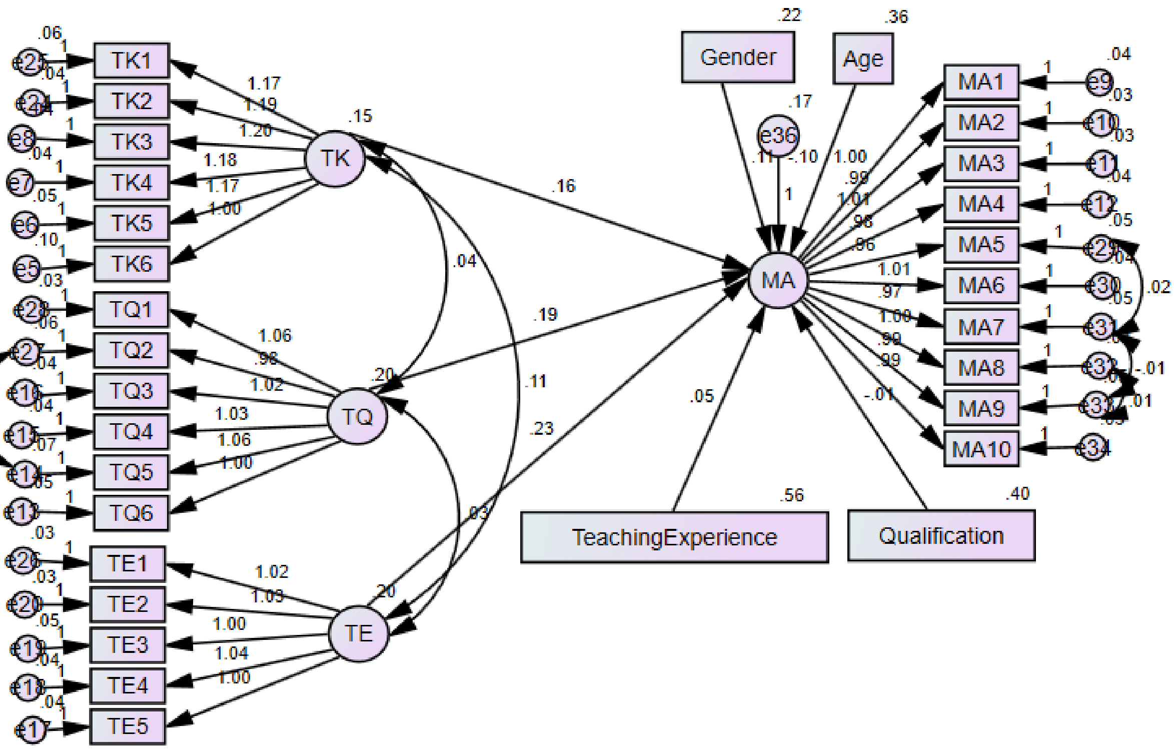
5.1.4. Control Variables

The study controlled for gender, age, highest qualification, and years of teaching experience. The control variables had the following impacts on mathematics achievement:

- Gender: The effect of gender on mathematics achievement was not statistically significant (β = .040, p =. 223), indicating that gender does not play a substantial role in influencing mathematics achievement in this context.
- Age: Age showed a negative but not statistically significant effect on mathematics achievement (β = −.042, p =.102), suggesting that age differences among students did not significantly impact their mathematics performance.
- Qualification: The highest qualification of teachers did not have a significant effect on mathematics achievement (β = −.029, p =. 233), indicating that other factors, such as teaching quality and experience, may be more influential.
- Teaching Experience: Teaching experience as a control variable had a significant positive effect on mathematics achievement (β = .059, p = .004), reinforcing the importance of experience in teaching efficacy.

The acceptance of all three hypotheses underscores the importance of teacher knowledge, teaching quality, and teaching experience in enhancing students' mathematics achievement through the implementation of RME. These findings suggest that professional development programs aimed at improving these teacher variables could be beneficial. The results also highlight the relatively minor role of demographic factors such as gender, age, and highest qualification compared to the significant impact of teaching-related variables.

Figure 3
Diagram of Path Estimates



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This study aimed to examine the impact of teacher variables, specifically teacher knowledge, teaching quality, and teaching experience—on learners' mathematics achievement through the implementation of RME in junior high schools in Ghana. Structural Equation Modeling was used to test the hypothesized relationships. The key findings are as follows:

1. **Hypothesis 1**: Teachers' knowledge has a direct positive effect on learners' mathematics achievement through the implementation of RME.

2. **Hypothesis 2**: Teaching quality has a direct positive effect on learners' mathematics achievement through the implementation of RME.
3. **Hypothesis 3**: Teaching experience has a direct positive effect on learners' mathematics achievement through the implementation of RME.

The SEM results presented in the table showed significant positive effects for the hypothesized relationships between teacher variables and mathematics achievement. Here, we discuss these findings in the context of existing literature and theoretical frameworks.

6. Discussion

6.1. Teachers' Knowledge and Mathematics Achievement

The acceptance of Hypothesis 1 confirms that teachers' knowledge significantly impacts learners' mathematics achievement. This finding aligns with previous research indicating that teachers' deep understanding of mathematics content is crucial for effective teaching and improved student outcomes (Hill et al., 2005). Similar findings have been reported in recent studies, emphasizing that teachers' subject knowledge is a strong predictor of learners' achievement (Goe et al., 2022). Moreover, a study by Telese (2012) found that professional development focused on deepening teachers' mathematical knowledge significantly improved student performance. Knowledgeable teachers can provide more accurate explanations, diagnose student misconceptions more effectively, and employ a wider variety of instructional strategies (Shulman, 2015). In the context of RME, teachers' knowledge enables them to create and facilitate learning experiences that are meaningful and relevant to students' real-life contexts, thereby enhancing understanding and retention.

6.2. Teaching Quality and Mathematics Achievement

Hypothesis 2, which posits that teaching quality has a direct positive effect on learners' mathematics achievement through the implementation of RME, was also supported. This result is consistent with Hattie's (2009) synthesis, which identifies high-quality teaching as a significant predictor of student success. High-quality teaching, characterized by clarity, engagement, and adaptability, fosters a conducive learning environment where RME can thrive. RME requires teachers to skillfully guide students through problem-solving processes and contextual applications of mathematical concepts (Van den Heuvel-Panhuizen, 2003). Therefore, teaching quality plays a pivotal role in the successful implementation of RME, leading to improved student achievement. Current literature corroborates this finding, highlighting that effective teaching practices, including clarity and engagement, significantly enhance student learning outcomes (Coe et al., 2014). For instance, a study by Praetorius et al. (2018) demonstrates that high-quality teaching practices lead to better learner engagement and higher achievement levels. In a contrary, a study by Asare et al. (2024) revealed that mathematics achievement was negatively impacted by teacher quality, but this effect was statistically significant. Hence to raise learners' mathematics achievement, teachers must use effective teaching and learning strategies like RME to gain learners' attention in mathematics teaching and learning.

6.3. Teaching Experience and Mathematics Achievement

The findings for Hypothesis 3 indicate that teaching experience has a positive effect on learners' mathematics achievement through the implementation of RME. This supports the notion that experienced teachers are more adept at managing classrooms, understanding student needs, and implementing innovative teaching strategies such as RME (Rice, 2010). Experienced teachers are likely to have developed a repertoire of skills and strategies that allow them to effectively engage students in meaningful mathematical tasks, a key component of RME (Kini & Podolsky, 2016). Other studies further support this, suggesting that experienced teachers are better equipped to implement complex instructional methods that improve student achievement (Kraft & Papay, 2014). Moreover, a study by Akiba et al. (2017) revirwed that teaching experience is positively correlated with learners' achievement in mathematics, underscoring the essence of experience in effective teaching.

6.4. Control Variables

The study controlled for gender, age, highest qualification, and years of teaching experience. Interestingly, these variables did not show significant direct effects on mathematics achievement. This underscores the importance of specific teacher variables (knowledge, quality, experience) over general demographic factors in influencing learners' outcomes. This finding is consistent with the broader literature, which often finds that specific instructional practices and teacher attributes have more substantial effects on student learning than demographic factors (Rockoff, 2004). For instance, a study by Rivkin et al., (2005) found that while teacher experience and content knowledge significantly impact student achievement, demographic factors such as age and gender do not have a significant direct effect. Asare et al. (2024) findings indicated that gender and age does not directly affect mathematics achievement in a statistically meaningful way.

7. Conclusion

This study brought new results to the existing literature in the field of mathematics education. These results contributed to a deeper understanding of the relationships between teacher variables: teacher knowledge, teaching quality, teaching experience and their impact on mathematics achievement within the context of RME in Ghanaian junior high schools. The acceptance of Hypothesis 1 underscores the significant role of teacher knowledge in enhancing mathematics achievement through the implementation of RME. This finding aligns with previous research emphasizing the importance of teachers' deep understanding of mathematical concepts and effective instructional strategies (Shulman, 1986). By grounding mathematical learning in real-world contexts, RME facilitated a more meaningful and engaging educational experience, thereby contributing to improved student performance. Similarly, Hypothesis 2 was supported, indicating that teaching quality positively influences mathematics achievement through RME. High-quality teaching practices, characterized by clear explanations, active engagement strategies, and effective classroom management, were found to enhance students' mathematical learning outcomes. This highlights the crucial role of pedagogical skills and instructional effectiveness in optimizing the benefits of RME for students in Ghanaian junior high schools. The findings also supported Hypothesis 3, demonstrating that teaching experience positively correlates with mathematics achievement through RME. Experienced teachers bring accumulated knowledge, refined instructional techniques, and better classroom management skills, which contribute to creating a conducive learning environment. Their ability to contextualize mathematical concepts within real-world scenarios under RME principles further enhances student engagement and comprehension.

8. Implications

The results of this study have several practical and policy implications:

Professional Development: There is a need for targeted professional development programs that enhance teacher knowledge and instructional quality, particularly in the context of RME. Training programs should focus on equipping teachers with the skills and knowledge necessary to implement RME effectively.

Curriculum Design: Integrating RME principles into the mathematics curriculum can provide students with more meaningful and engaging learning experiences. Educational policymakers should consider incorporating RME into national curricula to leverage its benefits for student achievement.

Teacher Support Systems: Establishing robust support systems for teachers, including mentoring, collaborative planning, and ongoing feedback mechanisms, can enhance teaching quality and self-efficacy. This, in turn, can lead to better student outcomes.

9. Future Directions

Future studies should explore the long-term effects of RME and other educational approaches on student achievement across diverse contexts. Longitudinal research could provide deeper insights into how teacher variables and instructional strategies influence student learning over time. Additionally, further investigation into the specific mechanisms through which teacher self-efficacy impacts teaching practices and student outcomes is warranted.

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