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Research Article

Modeling motivation: The effect of peer teaching on mathematics achievement

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This study investigated the mediating role and the moderating effect of motivation on the relationship between peer teaching and mathematics achievement. A descriptive correlation research design was utilized for this study. The analysis was based on primary data gathered using a structured questionnaire. The empirical analysis was based on 210 students in Ghana. Various validity and reliability checks were conducted before the presentation of the actual analysis, which was conducted using the structural equation modeling. The research findings revealed that peer teaching had a positive effect on mathematical achievement. In addition, peer teaching had a significant positive effect on motivation. Moreover, motivation had a significant positive effect on mathematics achievement. Furthermore, motivation positively mediates the relationship between peer teaching and mathematics achievement. Finally, motivation had a positive moderating effect on the relationship between peer teaching and mathematics achievement. Based on the study findings, teachers should use motivating, individualized learning, and goal-setting techniques to enhance student motivation and achievement in mathematics learning.

Keywords: Mathematics achievement, Motivation, Peer teaching

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1. Introduction

In the last two decades, there has been a consistent study on factors that negatively affect or positively improve students' mathematics achievement. Among them are peer teaching, mathematics interest, mathematics anxiety, motivation, and teacher qualities. Moreover, a student's mathematics achievement is a critical component of a well-rounded education, influencing not only an individual's academic success but also their future career prospects and problem-solving abilities. In the pursuit of enhancing mathematics education, educators and researchers have explored various teaching methods and strategies to improve students' performance in this subject. Peer teaching, a practice where students take on the role of educators for their peers, has gained increasing attention in recent years as a potentially effective approach to enhancing mathematics achievement.

Peer teaching is an instructional strategy in which students assume the roles of both teacher and learner (Abrahamson et al., 2023). Studies have shown a significant effect of peer teaching on student achievement (Bugaj et al., 2019; Lim et al., 2023). As documented by Santhanalakshmi and Naomi (2021), peer teaching, a practice in which students take on the role of educators for their peers, has been a subject of interest in the

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field of education for its potential to enhance mathematics achievement. In a similar study, Alegre et al. (2020) found that explaining mathematical concepts to peers leads to substantial learning gains, suggesting that peer teaching is an effective strategy for improving mathematics achievement. A study by DeFeo et al. (2023) found that peer tutors reported increased motivation and a sense of responsibility for their learning, which translated into improved mathematics performance among tutors and tutees. Research by Roberts and Spangenberg (2020) suggests that peer teaching in mathematics can be particularly effective for struggling students, as it offers them individualized assistance and builds their confidence. Beyond its effect on mathematics achievement peer teaching develops social and communication skills (Moliner & Alegre, 2020). According to Elshami et al. (2020), students who engage in teaching their peers often improve their ability to explain complex concepts, listen actively, and provide constructive feedback. The success of peer-tutoring programs depends on factors such as the quality of peer relationships, the expertise of peer tutors, and the level of cooperation among peers. Peer group dynamics can either enhance or inhibit the effect of peer teaching on mathematics achievement (Alegre et al., 2019; Choi et al., 2021).

Motivation describes the internal or external forces that propel people to pursue mathematical endeavors, persevere in resolving mathematical puzzles, and succeed in mathematics (DiNapoli, 2023). More motivated students are more likely to persevere in the face of difficulties or failures. According to research by Alamri et al. (2020), students who actively participate in educating their classmates feel a sense of autonomy and competence, which are crucial elements of intrinsic motivation. In addition, students' motivation is a key factor in their academic success. According to the Self-Determination Theory developed, competence and autonomy are crucial elements of motivation (Deci & Ryan, 2000). Students with a growth mindset are more likely to set mastery goals and persevere in the face of difficulties because they think their abilities can be developed through effort and learning (Bardach et al., 2020). The importance of task value in motivating students is emphasized in the literature (Bağdat & Yanık, 2023). Students are more motivated to do well in mathematics when they believe it to be personally relevant, fascinating, or vital. According to research by Ahn et al. (2021), students tend to be more motivated and perform better in mathematics when teachers offer positive feedback, foster a supportive classroom environment, and allow for some degree of student autonomy. Positive peer teaching and encouragement may boost students' motivation and academic achievement in mathematics (Shin & Bolkan, 2021).

A gap in the growing body of literature is the interplay between peer teaching, motivation, and mathematics achievement, which is limited in literature in mathematics education. There is a shortage of empirical studies that examine the moderating and mediating effect of motivation on the relationship between peer teaching and mathematics achievement. Several studies have concentrated on the influence of peer teaching on student's mathematics achievement (Razak & See, 2010) and the influence of motivation as a predictor of students' mathematics achievement (Habók et al., 2020; Moyano et al., 2020; Tella, 2007), without combining these constructs in a single study. To contribute to knowledge, we decided to examine the moderating and mediating effect of motivation on the relationship between peer teaching and students' mathematics achievement.

Ultimately, this study contributes to the understanding of how peer teaching influences student motivation in the context of mathematics learning. This study sheds light on how peer teaching influences student mathematics achievement. Moreover, this study provides insights into effective teaching strategies that can improve student performance in mathematics. In addition, understanding how peer teaching interventions influence mathematics achievement will inform the development of instructional practices to enhance student learning in mathematics. Furthermore, the findings of this study will inform educational practices and curriculum development efforts aimed at promoting student motivation and achievement in mathematics.

A conceptual framework of this study is in Figure 1. In Figure 1, peer teaching [PT] shows a direct effect on motivation [MoT] and mathematics achievement [MACH], motivation shows a direct effect on mathematics achievement, and motivation serves as both moderating and mediating role between on the relationship between peer teaching and mathematics achievement.

The following hypotheses were tested in the study:

H1: Peer teaching has a direct effect on mathematics achievement.

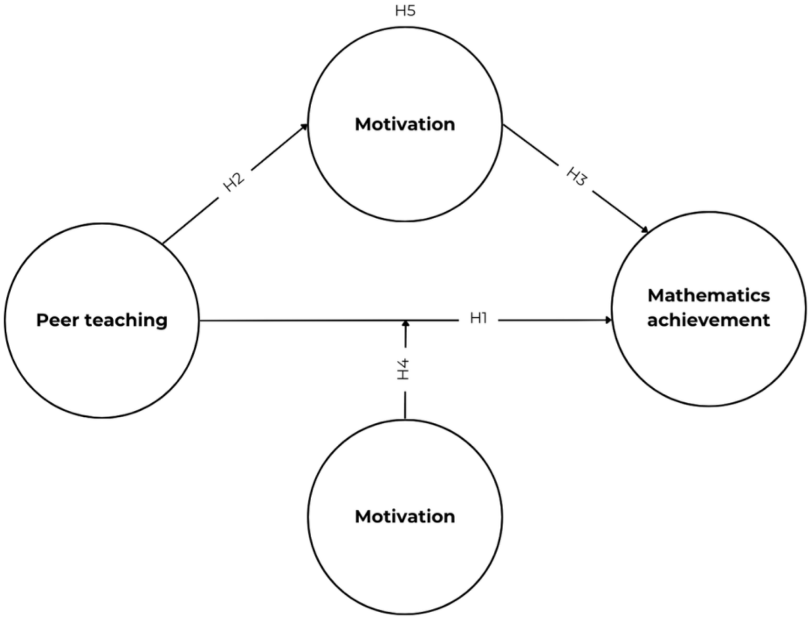
H2: Peer teaching has a positive effect on motivation.

H3: Motivation has a positive effect on mathematics achievement.

H4: Motivation moderates the relationship between peer teaching and mathematics achievement.

H5: Motivation mediates the relationship between peer teaching and mathematics achievement.

Figure 1
Conceptual Framework of the study



2. Method

This study adopted a descriptive-correlation research design. A descriptive-correlation design allows for efficient data collection through various survey methods, including online, paper, and telephone formats (Hsieh et al., 2023). This approach particularly benefits researchers seeking to gather information quickly and with minimal cost. Additionally, when conducted with a carefully structured sample, descriptive surveys can yield findings that apply to a wider population, enhancing the comprehension of the research issue.

2.1. Population and Sample

The population of this study consists of two senior high schools in the Ashanti Region of Ghana, with a target population of four hundred and forty-two students (442). The selected schools' students study mathematics as a compulsory subject. To calculate the sample size for the current study, Yamane's (1967) sample size determination approach was adopted which gives a sample size of 210 students. The selection process for respondents for this study was successful through stratified sampling and simple random sampling. Stratified sampling was used to categorize students into different stratum. The stratum for this study was their course of study, which includes, General Arts, Science, Agric, Business, and Visual Arts as presented in Table 1. Grouping the students according to their course of study will help the researchers to know the participants to use during the data collection process. After students were grouped based on their course of study, a simple random sampling approach was used to select the participants from each stratum for this study. This technique gave the students an equal chance to be selected. With the total sample size of 210 students, 69% (144) were males while 31% (66) were females. Moreover, concerning the age of the students, 41% (86) represent the age range from 16-19 years, 34% (71) represent the age range from 20-23 years, and 25% (53) represent the age of the students above 23 years. Finally, in terms of the course of study, 19% (40) of the sample students studied General Arts, 37% (77) studied Science, 18% (37) studied Agric Science, 25% (53) studied Business, and 1% (3) studied Visual Arts.

2.2. Ethical Considerations

To uphold data credibility and maintain strict adherence to ethical standards, a comprehensive set of measures was implemented. Ethical approval was obtained from the affiliated institutions of the authors, ensuring compliance with institutional guidelines and ethical research protocols. This approval specifically addressed critical aspects such as obtaining informed consent, safeguarding data privacy, and protecting against unauthorized access. Participants were thoroughly briefed about the purpose and scope of the study through a cover letter accompanying the distributed questionnaire. This letter provided detailed assurances that their responses would remain confidential and their identities would be anonymized. Furthermore, participants were informed of their rights, including the ability to withdraw from the survey at any point without any obligation or consequence.

2.3. Questionnaire and Measure

This study focused on three primary variables: peer teaching, motivation, and mathematics achievement (see Appendix I). These variables were evaluated using a five-point Likert scale, with responses ranging from 1-Strongly Agree to 5-Strongly Disagree. The scale allowed participants to express varying degrees of agreement or disagreement with specific statements related to each variable. The questionnaire was arranged into two parts. Part A comprises the demographic information of the respondents and part two comprises the statement under the main variables for this study that is, peer teaching, motivation, and mathematics achievement. All the measurement items under the observed variables were adapted from previous studies. Ten (10) measurement items were adapted from the work of Parkinson (2009) to measure peer teaching. Moreover, ten (10) measurement items were adapted from the work of Vlasenko et al. (2020) to measure motivation, and ten (10) measurement items were adapted from the work of Yu and Singh (2018) to measure mathematics achievement.

The study opted to use an existing questionnaire instead of developing a completely new one. This decision was guided by several important considerations. First, utilizing an established instrument ensured the use of scales and measures that had already been tested for reliability and validity in prior research. This not only reduced the time and effort required to create and validate new items but also facilitated comparisons with findings from previous studies. By leveraging established questionnaires, the study adhered to ethical research practices, ensuring content and construct validity as recommended by Hinkin and Tracey (2010). Using validated scales from prior empirical research has significant advantages. It minimizes the complexities associated with creating new measurement items. This approach allowed the researchers to focus on selecting items that specifically measured the constructs or variables central to the study's objectives. While the questionnaire was derived from existing research, adjustments were made to tailor it to the cultural and contextual setting of the target population. These modifications were necessary to enhance the relevance and applicability of the instrument. For example, the language used in the questionnaire was adapted to align with the educational and linguistic background of the study participants. This ensured that the items were not only clear and easily understood but also culturally sensitive, enabling participants to engage meaningfully with the survey. Although the core items were drawn from validated instruments, they were refined to align with the unique objectives and context of the study. We ensured that these modifications did not compromise the validity or reliability of the instrument. Instead, the adjustments enhanced the questionnaire's capacity to capture credible and meaningful data that reflected the study's specific aims and the characteristics of the population being studied.

2.4. Assessment of Common Method Bias–CMB

Common method variance [CMV] was examined in this study to ensure the validity of the findings, as data for all constructs were collected from a single source. According to Podsakoff and Organ (1986), CMV poses a significant threat to the validity of research results, making it a widely discussed issue in empirical studies. To address this concern, Harman's single-factor test was employed using exploratory factor analysis [EFA] to assess the extent of common method bias. The EFA results revealed that five distinct factors with eigenvalues greater than 1 collectively accounted for 67.055% of the total variance, while the first factor contributed only 19.354%. This finding indicates that common method bias was unlikely to be a concern in this study.

Further supporting the adequacy of the dataset for factor analysis, the Kaiser-Meyer-Olkin [KMO] Measure of Sampling Adequacy yielded a value of 0.921, signifying that the sample was well-suited for such an analysis, as per the guidelines of McNabb (2017). Additionally, Bartlett's test of sphericity was statistically significant (χ^2 = 2674.751, df = 95, determinant = 1.958E-01) at p < .001, confirming that the data were appropriate for factor analysis. Despite a sample size of 210, all statistical thresholds for data adequacy were met, reinforcing the robustness of the dataset. Therefore, the sample was deemed suitable for hypothesis testing, ensuring the reliability and validity of the study's results.

3. Results

3.1. Reliability and Validity Analysis

To assess the reliability and validity of the measurement model, the study employed Confirmatory Factor Analysis [CFA]. Several items were removed from the model due to low factor loadings or cross-loadings on multiple constructs, following the recommendations of Bagozzi and Yi (2012) and Asare and Larbi (2025). Table 1 presents the retained items used in the final model estimation. The analysis revealed that all items measuring peer teaching, motivation, and mathematics achievement had factor loadings exceeding 0.5.

Table 1
Confirmatory Factor Analysis and Model Fit Criteria

Model Fit Criteria: CMIN = 127.087; DF = 73; CMIN/DF = 1.741; TLI = .975; CFI= .980; GFI = .921; SRMR = .038; RMSEA = .060; PClose = .176	*Std. Factor Loadings*
Peer Teaching: CA = .938; CR = .957; AVE = .792	
PT2: I preferred peer learning to individual learning.	.742
PT3: My peer encouraged me to learn mathematics.	.764
PT4: My colleagues assisted me in solving mathematics tasks which I find challenging.	.855
PTE5: Peer teaching enhanced my understanding of mathematics learning.	.807
Motivation: CA = .922; CR = .928; AVE = .721	
MoT1: I usually feel relaxed when I am solving mathematics Questions.	.543
MoT2: The greatest gain in studying mathematics as part of my course of study is to help me think critically.	.765
MoT3: I feel comfortable with the mathematics that I learn relates to my personal goal.	.809
MoT4: I feel personal satisfaction when I can solve mathematics questions.	.783
MoT5: I learn mathematics because it gives me a sense of personal achievement.	.703
Mathematics Achievement: CA = .933; CR = .937; AVE = .748	
MACH3: Mathematics comes easy to me.	.731
MACH4: No matter how much I study, mathematics always presents a challenge to me.	.776
MACH5: I am more worried about my mathematics achievement than any other subject.	.833
MACH6: My achievement in mathematics is not encouraging.	.765
MACH7: I often do my mathematics assignments after school.	.635

Cronbach's alpha, which measures internal consistency, is expected to be at least 0.7. However, all three dimensions recorded alpha scores above 0.8, indicating high internal consistency. Similarly, composite reliability [CR] is expected to be at least 0.7, and the results showed that all dimensions had CR values above 0.8, further confirming strong internal consistency among the items. Convergent validity was assessed using the Average Variance Extracted [AVE], where a threshold of 0.5, as proposed by Fornell and Larcker (1981), indicates sufficient validity. As shown in Table 1, all AVE values exceeded 0.5, confirming convergent validity for the constructs.

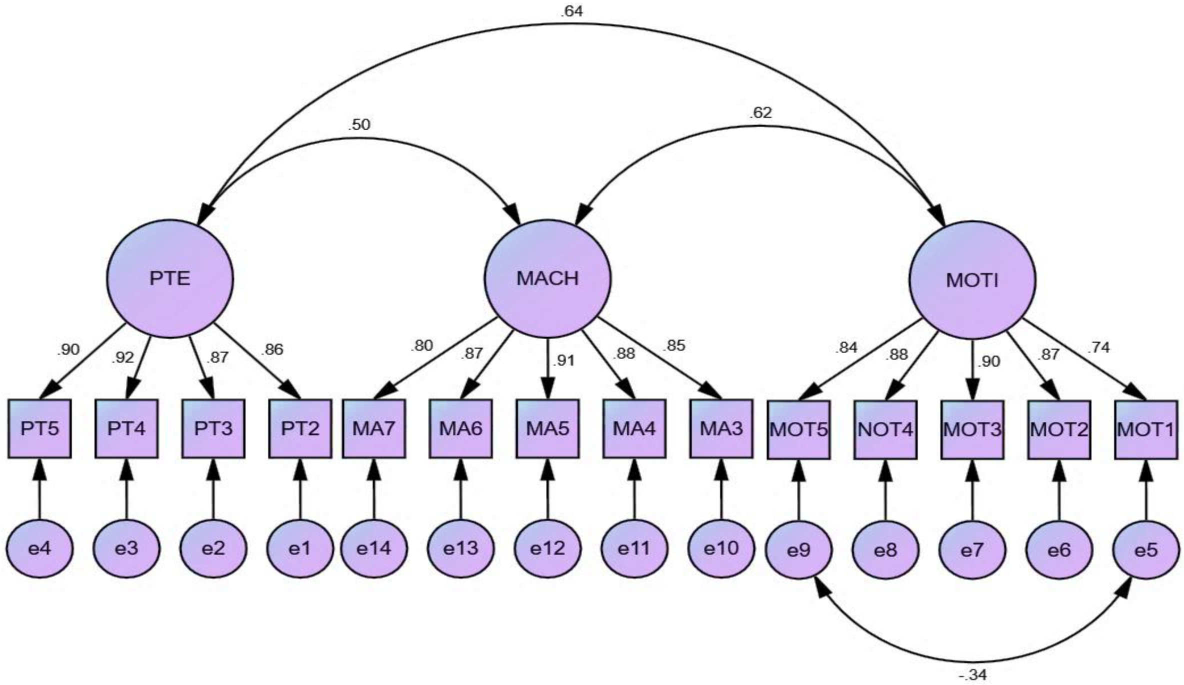
Regarding model fit, the chi-square statistic (χ^2) divided by degrees of freedom [df] should be less than 3 (Arthur et al., 2025; Asare, 2024), and this criterion was met for all three constructs. Additionally, the p-values for χ^2 were statistically insignificant, aligning with expectations (Hu & Bentler, 1999). The root mean square error of approximation [RMSEA] and standardized root mean square residual [SRMR] are expected to be below 0.08 (Kline, 2018), while the comparative fit index [CFI] and Tucker-Lewis index [TLI] should be above 0.95 (Dogbe et al., 2024; Kline, 2018). As shown in Table 1, all these fit indices met the required thresholds, confirming the model's adequacy for estimation. Finally, the coefficient of determination for all constructs exceeded 0.7, indicating that the observed items explained more than 70% of the variance in their respective latent variables, ensuring the model's validity and reliability.

3.2. Confirmatory Factor Analysis Illustration

Figure 2 shows the diagrammatic form for the confirmation factor analysis as presented in Table 2. From Figure 2 the measurement items PT2, PT3, PT4, and PT5 are the various questions on the questionnaire purposely for measuring peer teaching. Moreover, the measurement items MACH3, MACH4, MACH5, and

MACH6 are the various questions on the questionnaire purposely to measure mathematics achievement. In addition, the measurement items MoT1, MoT2, MoT3, MoT4, and MoT5 are the various questions on the questionnaire purposely for measuring motivation. Also, Figure 2 shows the correlation between peer teaching and mathematics achievement, peer teaching and motivation, and motivation and mathematics achievement. Finally, e9 and e5 were joined purposely for model fitness.

Figure 2
Confirmatory Factor Analysis



To evaluate discriminant validity, the square root of the Average Variance Extracted values must be compared with the correlation coefficients among the constructs. According to Fornell and Larcker (1981) criterion, discriminant validity is established when the square root of the AVE for a construct is greater than its highest correlation with any other construct. This condition ensures that the construct explains more variance in its associated indicators than it shares with other constructs in the model. From the results presented in Table 2, it was observed that the square root of the AVE for each of the three constructs exceeded their corresponding intercorrelation values, satisfying the Fornell-Larcker criterion for discriminant validity. This finding suggests that each construct is unique and distinct, indicating that the indicators used for measurement effectively capture their intended latent variable without significant overlap with other constructs.

The confirmation of discriminant validity holds significant implications for the reliability and interpretability of the measurement model. When constructs exhibit discriminant validity, it implies that each variable measures a distinct concept, reducing concerns about redundancy or multicollinearity among variables. In this study, the results indicate that the observed items effectively differentiate between the constructs they were designed to measure, strengthening the credibility of the model. This outcome also enhances the robustness of subsequent structural model analyses, ensuring that the relationships among constructs can be interpreted with confidence. By meeting the discriminant validity requirement, the study confirms the theoretical soundness of its measurement framework, reinforcing the reliability of the conclusions drawn from the research findings.

Table 2
Discriminant Validity

Variables	*CR*	*AVE*	*MSV*	*MaxR(H)*	*PTE*	*MOTI*	*MACH*
PTE	.957	.792	.406	.940	**.980**		
MOTI	.928	.721	.406	.936	.637***	**.849**	
MACH	.937	.748	.389	.942	.496***	.624***	**.865**

3.3. Path Estimates

The path analysis was performed using Amos (v. 23) based on a covariance-based structural equation modeling [SEM] framework. The analysis utilized 5,000 bootstrap samples at a 95% confidence interval, employing a bias-corrected percentile bootstrapping method to enhance the accuracy and reliability of the estimated parameters. This methodological approach ensures that parameter estimates are statistically sound, minimizing errors associated with sampling variability. By employing Amos (v. 23) with bootstrapping and bias correction, the analysis achieves higher accuracy in determining direct and indirect effects within the path model. From the path summary (Table 3 and Figure 3), age and gender negatively influenced mathematics achievement ($\beta = -.023$, C.R = $-.333$; $\beta = -.030$, C.R = $-.252$). Students' course of study directly and significantly influenced their mathematics achievement ($\beta = .224$, C.R = 4.412).

Table 3
Path summary

Direct Effect	*Std. Estimates*	*SE*	*C.R*	*p-value*
Gender→MACH	-.030	.119	-.252	.630
Age→MACH	-.023	.069	-.333	.710
Course→MACH	.224	.051	4.412	<.001
PTE→MACH	.165	.094	1.755	.038
PTE→MOTI	.637	.109	5.844	<.001
MoTI→MACH	.395	.109	3.624	<.001
Indirect Effect	*Std. Estimate*	*Lower B.*	*Upper. B*	*p-value*
PTE→MOTI→MACH	.105	.003	.239	.006
Moderating Effect	*Std. Estimate*	*S. E*	*C.R*	*p-value*
PTE_MOTI→MACH	.232	.010	3.703	<.001

For the hypothesized paths, peer teaching demonstrated a significant direct positive impact on mathematical achievement, as indicated by a standardized regression weight (β) of 0.165 and a critical ratio of 1.755. The *p*-value, not exceeding the 5% threshold, confirms the statistical significance of this effect, implying that the likelihood of this result occurring by chance is minimal. This suggests that when students engage in teaching their peers, it enhances their mathematical understanding and performance, likely due to increased cognitive engagement, reinforcement of concepts, and the collaborative learning environment fostered during the process. H1 was therefore accepted by the analysis.

Moreover, the results indicate that peer teaching positively influences student motivation, as evidenced by a statistically significant effect at the 1% level. The standardized regression coefficient (β = 0.637) demonstrates a strong and meaningful relationship, suggesting that peer teaching accounts for a substantial proportion of the variance in motivation. The critical ratio (C.R = 5.844) further supports the robustness of this finding, as it exceeds the commonly accepted threshold of 1.96 for statistical significance at the 5% level, confirming the reliability of the effect at an even stricter 1% threshold. This result highlights the effectiveness of peer teaching strategies in fostering motivation, emphasizing its potential as a valuable pedagogical tool for enhancing student engagement and interest in learning. H2 was therefore accepted by the analysis.

In addition, motivation was found to have a significant and positive impact on mathematics achievement, as evidenced by a standardized regression coefficient (β) of 0.395 and a critical ratio of 3.623. The *p*-value, which does not exceed 1% ($p \leq .01$), indicates a highly statistically significant relationship. This finding suggests that higher levels of motivation among students are strongly associated with better performance in mathematics. The positive β value confirms that as motivation increases, mathematics achievement improves proportionally, emphasizing the critical role of intrinsic and extrinsic motivation in enhancing academic outcomes in mathematics. Therefore, H3 was thus supported by the analysis.

Also, peer teaching has a strong indirect effect on mathematics achievement through motivation with a *p*-value not exceeding 1% (β = .105), indicating that peer teaching indirectly affects mathematics achievement through motivation. This means that motivation partially mediates the relationship between peer teaching and mathematics achievement with an effective size of 10.5%. Therefore, H4 was thus supported by the analysis.

Finally, the moderation effect of motivation is presented in Table 5 and Figure 4. The moderating effect of PTE_MOT on mathematics achievement is significant with a *p*-value of less than 1% (β = .232, C.R = 3.703), suggesting that the level of motivation positively affects the link between peer teaching and mathematical achievement. Thus, there is a 23.2% moderating effect of students' motivation in the relationship between peer teaching and mathematics achievement. Therefore, H5 was thus supported by the analysis.

Figure 3
Path diagram

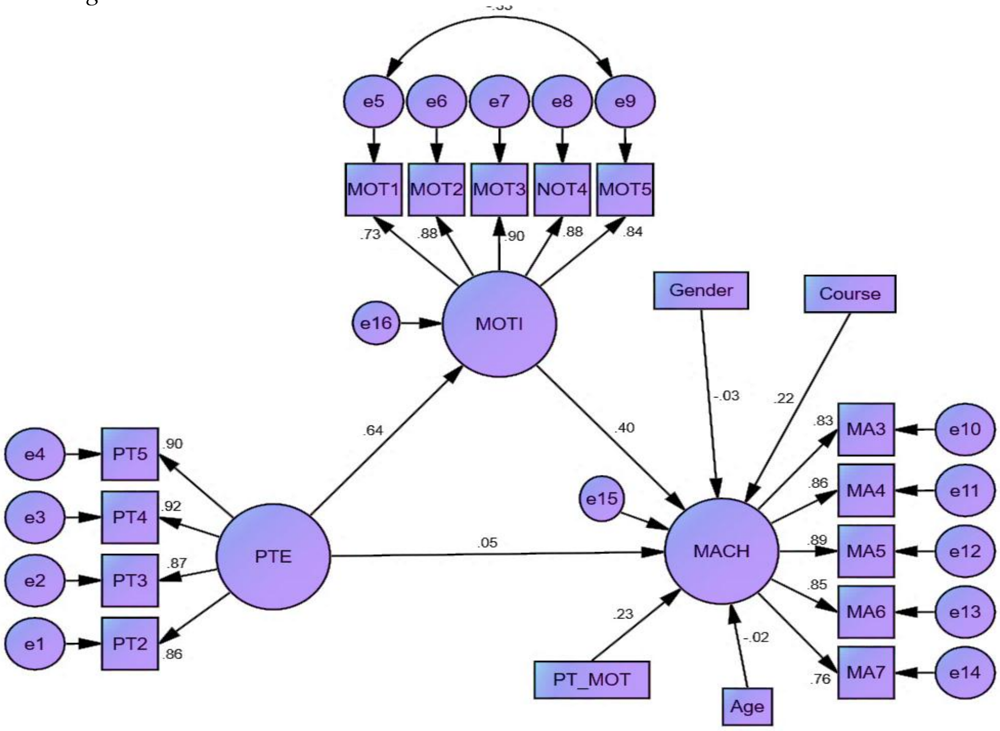
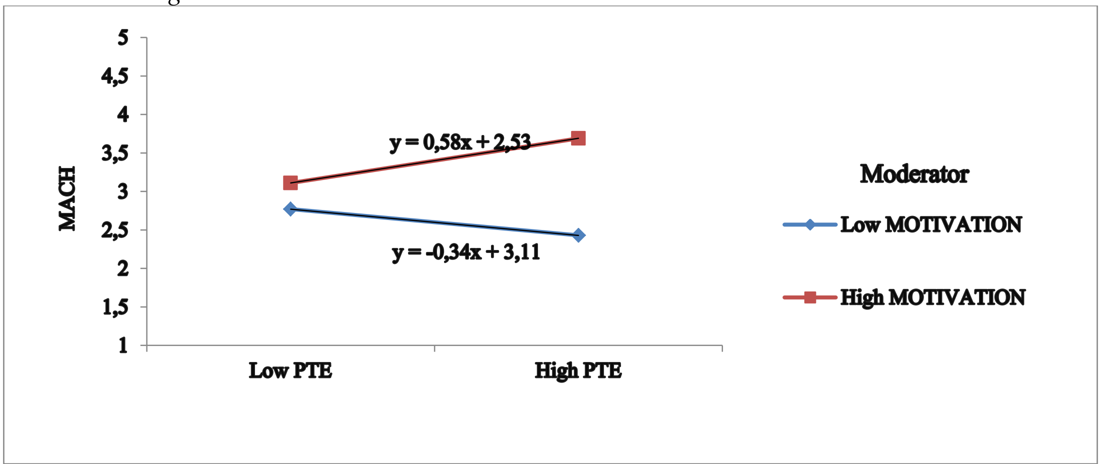


Figure 4
Moderation diagram



The moderation diagrams (see Figure 4) show that motivation strengthens the positive relationship between peer teaching and mathematics achievement. Peer teaching and motivation have significant effects on mathematics achievement. This means that when students teach their colleagues to help them understand concepts or difficult tasks and they are motivated as well, their mathematics achievement will improve.

4. Discussion

With the sample size of 210 students from the two Senior High Schools in the Ashanti Region, Ghana, it was identified from the study findings in Table 5 and Figure 3 that, peer teaching had a positive effect and was statistically significant on students' mathematics achievement. This finding conformed with past studies such as Lim et al. (2023), whose study focused on the effect of peer learning and self-regulated learning on academic achievement using blended learning with 409 respondents where 347 of the total respondents were valid for the data analysis. The result from their analysis confirmed that peer learning had a significant positive effect on academic achievement. Similarly, Santhanalakshmi and Naomi (2021) conducted a study to determine whether the peer teaching strategy had significantly enhanced the academic achievement of students at the secondary level. The students were grouped into a control group and an experimental group. Her result after the study showed that the experimental group performed higher than the control group which confirmed with the current study that peer teaching has a significant effect on students' mathematics achievement. In a similar vein, Parkinson (2009) found that peer teaching enhanced students' performance in mathematics which confirmed with the current study that, peer teaching had a positive effect on mathematics performance but was statistically insignificant.

In addition, the study found that the effect of peer teaching on motivation was positive and statistically significant. This finding conformed with past studies such as Sullivan (2020), whose study presents empirical evidence showing that students involved in peer teaching report higher levels of motivation and engagement in their academic pursuits compared to those learning in traditional settings. In a similar vein, Alegre et al. (2020) found that peer teaching improved motivation, conceptual understanding, and problem-solving skills in mathematics. In a study by Engels et al. (2021), peer teaching was found to have significant positive effects on motivation. Moreover, Oh et al. (2022) conducted a meta-analysis that included various studies on peer teaching. The results showed that peer teaching had a moderate effect on mathematics achievement. The effect size is compared to other effective teaching strategies such as feedback and formative assessment. Another study by Bhat et al. (2022) explored the effect of peer teaching on mathematics achievement in primary school students. The results indicated that peer assistance had a positive effect on mathematical understanding and problem-solving skills. Their study also found that students in peer teaching groups showed higher levels of motivation and engagement in mathematics.

Moreover, motivation had a significant positive effect on students' mathematics achievement. The result validates the study of Liu et al. (2020), in their study found that motivation had a positive effect on mathematics achievement and was statistically insignificant which confirmed the current study result. Tran and Nguyen (2021) examine the relationship between motivation and mathematics achievement. Their result contradicts the current study findings that is, motivation negatively correlates with mathematics achievement.

Furthermore, peer teaching had a positive effect and statistically significant effect on mathematics achievement. This finding aligned with the findings of Khan et al. (2021). Their study found that peer teaching had a positive significant effect on students' motivation. Also, Engels et al. (2021) support the finding that peer teaching has a positive significant effect on students' motivation. The study found that motivation partially mediates the relationship between peer teaching and mathematics achievement. The current study adds to the body of literature by investigating how motivation mediates the relationship between peer teaching and mathematics achievement.

Finally, the current study ended that, the moderating roles of motivation on the link between peer teaching and mathematics achievement was both positive and statistically significant. The findings suggest that when students take on the role of a teacher to instruct their peers, it enhances their motivation to grasp mathematical concepts, theorems, and formulas. The relationship between peer teaching and mathematics achievement, or the moderating construct between the direct relationship that is, the association between peer teaching and mathematical achievement, is the key innovation that this study adds to the body of literature. According to the current study, motivation positively moderates the relationship between peer teaching and mathematics achievement.

5. Conclusion

This study investigates the mediation role and moderation effect of motivation in the relationship between peer teaching and mathematics achievement. The population for this study comprises two senior high schools in the Ashanti Region of Ghana with a total of 442 students with a total of 2672 students. Stratified sampling and simple random sampling techniques serve as the main sampling techniques for the study. The study adopted a descriptive design utilizing a structured questionnaire. The study data was analyzed using Structural Equation Modeling in Amos (v.23) to estimate the hypothesized paths. The research findings revealed that peer teaching had a positive effect on mathematical achievement. In addition, peer teaching had a significant positive effect on motivation. Moreover, motivation had a significant positive effect on mathematics achievement. Furthermore, motivation positively mediates the relationship between peer teaching and mathematics achievement. Finally, motivation had a positive moderating effect on the relationship between peer teaching and mathematics achievement.

6. Limitations and Suggestions for Further Study

This study may have concentrated on a particular demographic or setting, which restricts its applicability to a larger group. For the findings to apply to a wider spectrum of students and educational environments, future studies should include more varied samples. Future research could benefit from combining quantitative and qualitative techniques to better understand students' motivation, including their intrinsic and extrinsic incentives. Although this study may have found associations between peer teaching, motivation, and mathematical achievement, it may not have conclusively demonstrated a causal relationship. More persuasive evidence of causality may be provided by experimental designs or longitudinal research. This study may have placed a lot of emphasis on immediate results. Further research is needed to examine the long-term effect of peer teaching on mathematical achievement and motivation, as well as how these effects change or remain over time.

7. Recommendations

Based on the findings educational institutions should implement structured peer teaching programs. These programs can be organized by pairing students with varying levels of mathematical proficiency, fostering a collaborative environment. Teachers should train peer tutors in effective instructional strategies, emphasizing problem-solving techniques and concept clarification. Incorporating peer teaching sessions into the regular curriculum can also provide consistent reinforcement of concepts, ensuring both tutors and tutees gain a deeper mathematical understanding. Moreover, schools should design peer teaching activities that actively engage students. Incorporating gamification, such as math challenges or collaborative problem-solving competitions, can boost motivation. Additionally, providing recognition or rewards for active participation in peer teaching can encourage students to take these activities seriously. Teachers should also ensure that the learning environment during peer teaching sessions is supportive and inclusive, addressing the diverse needs of students to maximize motivation. In addition, providing professional development sessions that equip teachers with skills to design, monitor, and evaluate peer teaching sessions is essential. These sessions should include techniques to identify suitable student pairings, ways to provide constructive feedback, and methods for fostering a positive and collaborative classroom culture. Teachers should also be trained to track motivation levels in students, ensuring they can intervene promptly if motivation dips. Finally, educational stakeholders should incorporate activities that enhance intrinsic motivation, such as real-life applications of mathematical concepts discussed in peer teaching sessions. Providing students with autonomy to design their peer teaching tasks or problems can also boost engagement and ownership of learning. Schools should also adopt tools to assess and track changes in student motivation over time, ensuring that the benefits of peer teaching on mathematical achievement are sustained.

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

Data Availability: The corresponding author has access to the data supporting the findings of this study upon request.

Declaration of interest: The authors have no conflict of interest to declare regarding the content of this article.

Ethics declaration: The authors stated the study did not require formal ethical approval. However, they observed and adhered to the ethical practices applicable to scientific research.

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Appendix 1. Research Questionnaire

Please mark (√) where applicable. It will take roughly 20 minutes to complete the entire questionnaire.

Section A: Demographics

1. Gender: Male [] Female []
2. Age: 12-17 years [] 18-25 years [] Above 25 years []
3. Course of Study: General Arts [] Science [] Agric Science [] Business [] Visual Arts []

Section B: Peer Teaching; Mathematics Motivation; and Mathematics achievement;

Q4. Please indicate your level of agreement or disagreement with the statement below. They have been rated in the form *1-Strongly Agree, 2-Agree, 3-Neutral, 4-Disagree, and 5-Strongly Disagree.*

Please Tick (√) in the box where appropriate.

CODE	***Peer Teaching***	***1=SA***	***2=A***	***3=N***	***4=D***	***5=SD***
PT1	My colleagues assisted me in learning mathematics.	[1]	[2]	[3]	[4]	[5]
PT2	I preferred peer learning to individual learning.	[1]	[2]	[3]	[4]	[5]
PT3	My peer encouraged me to learn mathematics.	[1]	[2]	[3]	[4]	[5]
PT4	My colleagues assisted me in solving mathematics tasks which I find challenging.	[1]	[2]	[3]	[4]	[5]
PT5	Peer teaching enhanced my understanding of mathematics learning.	[1]	[2]	[3]	[4]	[5]
PT6	I feel more confident in my learning after participating in peer teaching sessions.	[1]	[2]	[3]	[4]	[5]
PT7	Explaining concepts to my peers helps me reinforce my own knowledge	[1]	[2]	[3]	[4]	[5]
PT8	I actively engage in peer teaching sessions to improve my academic performance.	[1]	[2]	[3]	[4]	[5]
PT9	My peers explain concepts in a way that is easy to understand.	[1]	[2]	[3]	[4]	[5]
PY10	Peer teaching improves my critical thinking and problem-solving skills.	[1]	[2]	[3]	[4]	[5]
CODE	***Motivation***	***1=SA***	***2=A***	***3=N***	***4=D***	***5=SD***
MOT1	I usually feel relaxed when I am solving mathematics Questions.	[1]	[2]	[3]	[4]	[5]
MOT2	The greatest gain in studying mathematics as part of my course of study is to help me think critically.	[1]	[2]	[3]	[4]	[5]
MOT3	I feel comfortable with the mathematics that I learn relates to my personal goal.	[1]	[2]	[3]	[4]	[5]
MOT4	I feel personal satisfaction when I can solve mathematics questions.	[1]	[2]	[3]	[4]	[5]
MOT5	I learn mathematics because it gives me a sense of personal achievement.	[1]	[2]	[3]	[4]	[5]
MOT6	I feel motivated to solve challenging mathematical problems.	[1]	[2]	[3]	[4]	[5]
MOT7	I believe that improving my mathematics skills will benefit my future career.	[1]	[2]	[3]	[4]	[5]
MOT8	I put in extra effort to understand mathematical concepts even when they are difficult.	[1]	[2]	[3]	[4]	[5]
MOT9	I am eager to participate in mathematics-related activities inside and outside the classroom.	[1]	[2]	[3]	[4]	[5]
MOT10	I seek help or additional resources to improve my understanding of mathematics.	[1]	[2]	[3]	[4]	[5]
CODE	***Mathematics Achievement***	***1=SA***	***2=A***	***3=N***	***4=D***	***5=SD***
MA1	My achievement in mathematics is low.	[1]	[2]	[3]	[4]	[5]
MA2	I have confidence that I will perform better in mathematics.	[1]	[2]	[3]	[4]	[5]
MA3	Mathematics comes easy to me.	[1]	[2]	[3]	[4]	[5]
MA4	No matter how much I study, mathematics always presents a challenge to me.	[1]	[2]	[3]	[4]	[5]
MA5	I am more worried about my mathematics achievement than any other subject.	[1]	[2]	[3]	[4]	[5]
MA6	My achievement in mathematics is not encouraging.	[1]	[2]	[3]	[4]	[5]
MA7	I often do my mathematics assignments after school.	[1]	[2]	[3]	[4]	[5]
MA8	Some mathematics assignments are difficult to understand.	[1]	[2]	[3]	[4]	[5]
MA9	I usually perform well in mathematics class tests.	[1]	[2]	[3]	[4]	[5]
MA10	Mathematics class test questions are more understandable than exam questions.	[1]	[2]	[3]	[4]	[5]