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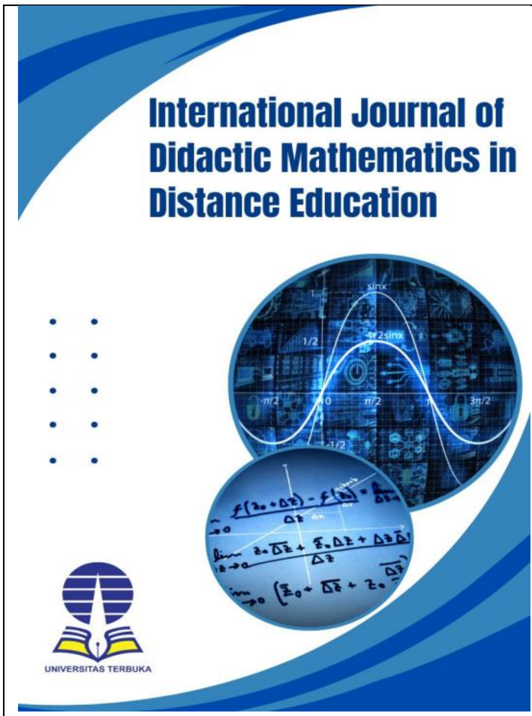

Influence of peer learning, self-regulatory learning, and mathematics interest on mathematics performance

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Influence of peer learning, self-regulatory learning, and mathematics interest on mathematics performance

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Abstract
The current study examined the influence of peer learning, self-regulatory learning, and mathematics interest on mathematics performance. The study adopted descriptive survey using questionnaire for the data collection. 320 students were sampled from a total population of 1600 students using stratified sampling and simple random sampling techniques. The data collected was analysed using Structural equation modeling to examined the hypothesized paths. Based on the data analysis, peer learning, self-regulatory learning, and mathematics interest had a direct positive and statistically significant impact on mathematics performance. The study explores the impact of peer learning, self-regulatory learning, and mathematics interest on students' performance, offering insights for effective instructional strategies and policy interventions. Finally, the study suggests incorporating structured peer-learning activities, self-regulatory learning strategies, engaging mathematical contexts, and professional development programs for teachers to enhance student autonomy and interest in mathematics.

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1. Introduction

In the realm of education, understanding the multifaceted dynamics that influence students' academic performance in mathematics has long been a subject of intense investigation. Mathematics is considered as compulsory subject for student to study in Ghana (Oduro, 2015). Mathematics as a course serve as a gateway for student to proceed to any tertiary institution in Ghana. Most students ended their level of education mostly at the senior high school due to failure in mathematics during their final examination (Chand et al., 2021). This has led to several investigation upon the factors that negative affect student performance in mathematics in Ghana.

Several studies had examined factor that negatively influence students' mathematics performance. In the study of Edo and Asare (2024) found students anxiety in mathematics learning negatively affect student performance in mathematics learning. Moreover, Bah (2022) found that lack of personal status, erroneous beliefs, students, teachers, teaching methods, language competence, teaching and learning materials, parents and family members, schools, policies, society, infrastructures; and government had negatively effect on students mathematics performance. In a similar vein, Berger et al. (2020) emphasized that student perceived mathematics perception has a negative influence on their mathematics performance.

Peer learning, often recognized as a collaborative learning approach, leverages the collective knowledge and experiences of peers to enhance understanding and problem-solving skills. Through peer interaction, students not only reinforce their comprehension of mathematical concepts but also develop crucial communication and teamwork abilities. The effectiveness of peer learning in mathematics education has garnered significant attention, as it not only cultivates a supportive learning environment but also fosters a deeper conceptual understanding through discussions and collaborative problem-solving. Furthermore, self-regulatory learning strategies encompass a range of cognitive and metacognitive techniques that empower students to take control of their learning processes. From goal setting to monitoring progress and adapting strategies, self-regulated learners exhibit greater autonomy and efficacy in navigating mathematical challenges. By actively managing their cognitive resources and employing effective learning strategies, students can optimize their mathematical learning experiences and achieve higher levels of performance. Moreover, individual interest in mathematics serves as a powerful motivational force that can significantly influence students' engagement and perseverance in learning mathematical concepts. When students possess a genuine curiosity and passion for mathematics, they are more likely to invest time and effort in exploring complex problems, seeking deeper understanding, and overcoming obstacles. The interplay between intrinsic interest and academic achievement underscores the importance of nurturing students' enthusiasm for mathematics as a catalyst for success.

Problem Statement

In contemporary education, mathematics performance stands as a crucial determinant of students' academic success and future prospects. However, achieving proficiency in mathematics poses a significant challenge for many students, necessitating a deeper understanding of the factors influencing their performance in this critical subject. Studies in mathematics education have examined influential factors that positively or negative influenced student's performance in mathematics learning. Several studies focused on students' peer assisted learning, mathematics interest, motivation, and perceptions as factors that account for low performance in mathematics (Moliner & Alegre, 2022; Kalpana et al., 2019). Concentrating on students' peer assisted learning, self-regulation learning, and mathematics interest as a predictor of student's mathematics performance might not be the enough variables that positive or negatively influence students' mathematics performance.

Despite the wealth of research on each of these factors individually, limited attention has been given to examining their combined effects on student mathematics performance within the context of diverse student populations. Therefore, this study seeks to address this gap by investigating the interplay between peer learning, self-regulatory learning, and mathematics interest in shaping students' mathematical proficiency.

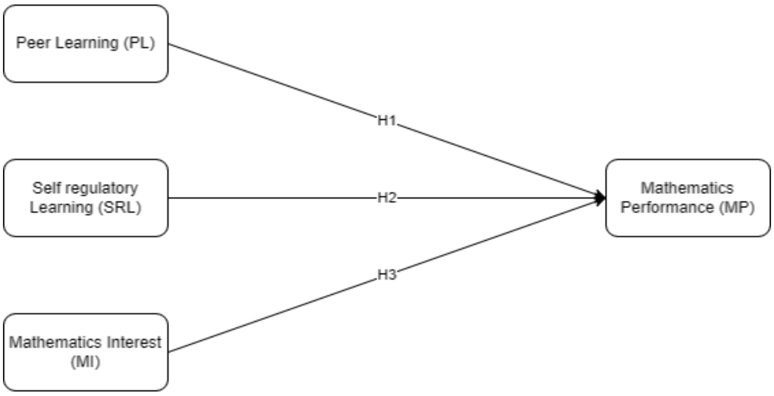
Research questions

1. What effect does peer learning has on students matheamtics performance?
2. Does self-regulatory learning significantly influence students mathematics performasnce?
3. Does students mathematics inteerst significantly influence their mathematics performasnce?

Conceptual Framework

Figure 1 shows the conceptual framework for the current study. From Figure 1, peer learning, self-regulatory learning, and mathematics interest are the independents variables whiles mathematics performance is the dependent variable. Moreover, peer learning has a direct effect on mathematics performance, self-regulatory learning has a direct effect on mathematics performance, and mathematics interest has a direct effect on mathematics performance as display in Figure 1.

Figure 1
Conceptual Framework



Literature Review

Peer teaching and mathematics performance

Peer teaching, also known as peer tutoring or peer-assisted learning, refers to students teaching other students in an educational setting. The effect of peer teaching on mathematics performance has been widely studied, and numerous pieces of literature support its effectiveness. Peer teaching has been shown to enhance students' understanding and mastery of mathematical concepts. When students teach their peers, they reinforce their own understanding of the material. A study by Moeyaert et al. (2021) found that peer tutoring had a significant positive effect size (d=0.55) on student achievement in mathematics, indicating that it is an effective instructional strategy. Peer teaching often fosters a more interactive and engaging learning environment compared to traditional teacher-led instruction. Students may feel more comfortable asking questions to their peers and engaging in discussions. A meta-analysis by Roscoe and Chi (2007) suggests that collaborative learning approaches, such as peer teaching, promote deeper learning and better conceptual understanding in mathematics. Peer teaching not only benefits the academic performance of students but also helps in the development of communication and social skills. Students learn to explain complex concepts in simpler terms, thereby improving their own communication skills. Research by Thurston et al. (2020) highlights the social and personal benefits of peer tutoring, including increased self-esteem and improved communication skills. Peer teaching promotes active learning, which has been linked to better retention and transfer of knowledge. When students engage in teaching others, they deepen their understanding of the material and are better able to apply it in different contexts. Tsuei (2012) suggest that peer teaching facilitates the transfer of knowledge from one context to another, leading to improved problem-solving skills in mathematics.

Self-regulatory learning and Mathematics performance

Self-regulatory learning (SRL) refers to the process by which learners set goals, monitor their progress, and regulate their cognition, motivation, and behavior to achieve those goals. In the context of mathematics performance, SRL plays a crucial role as it empowers students to take control of their learning process, which can lead to improved academic achievement. Self-regulated learners set specific, challenging, and achievable goals in mathematics. They plan how to approach a mathematical problem or concept effectively. By setting clear objectives, students are more focused and motivated to engage in mathematical tasks. Yıldızlı and Saban (2016) emphasizes the importance of goal setting and planning in self-regulated learning, showing that students who set specific goals perform better in mathematics. Self-regulated learners continually monitor their understanding and progress in mathematics. They assess their comprehension of mathematical concepts and identify areas where they need improvement. Al Mutawah et al. (2017) found that students who monitor their progress in mathematics have better problem-solving skills and achieve higher mathematics grades. elf-regulated learners employ various strategies to solve mathematical problems efficiently. They use metacognitive strategies such as self-questioning, self-explanation, and summarization to deepen their understanding of mathematical concepts. Kirschner et al.

(2022) suggests that students who use metacognitive strategies perform better in mathematics. Miller and Hadwin (2015) argue that adaptive strategies are essential for successful mathematical problem-solving. Yazgı and Afat (2022) found that students who regulate their emotions effectively perform better in mathematics. Chatzistamatiou and Dermitzaki (2013) highlights the importance of self-reflection in enhancing mathematics performance.

Mathematics Interest and Mathematics Performance

The relationship between mathematics interest and mathematics performance has been a subject of interest in educational psychology and related fields. Numerous studies have examined how students' interest in mathematics impacts their performance in the subject. Interest in mathematics is often associated with higher levels of motivation and engagement in learning activities. When students are interested in a subject, they are more likely to invest time and effort into understanding concepts and practicing problem-solving. A study by Laine et al. (2020) titled "Revisiting the Conceptualization, Measurement, and Generation of Interest" explores the role of interest in learning and highlights its impact on academic performance. Students with a genuine interest in mathematics are more likely to persist in challenging tasks and exert effort to overcome obstacles. Their intrinsic motivation drives them to seek solutions and deepen their understanding of mathematical concepts.

This perseverance often leads to better performance outcomes. Ahn et al. (2021) discuss the importance of intrinsic motivation in academic achievement in their Self-Determination Theory. Mathematics interest contributes to the development of positive attitudes toward the subject. Students who find mathematics interesting are more likely to perceive it as valuable and relevant to their lives. This positive attitude can foster a growth mindset, where students believe in their ability to improve and succeed in mathematics (Jaffe, 2020). A study by Draijer et al. (2020) titled " The Multidimensional Structure of Interest " provides insights into how interest influences learning and achievement. Mathematics interest can contribute to students' emotional well-being and overall academic satisfaction. Enjoyment of the subject can reduce anxiety and stress associated with mathematics learning, creating a positive learning environment conducive to higher performance (Liu et al., 2022). Moreover, a study Asare et al. (2024) conducted a study on 300 firs year students to examine the effect of mathematics interest on their mathematics performance using structural equation model for the data analysis. The result from their study found that, interest in mathematics had a significant effect on student mathematics performance. Edo and Asare (2024) in their study found that student mathematics interest positively moderates the connection between student math attitude and mathematics achievement.

2. Method

2.1. Design Research

This study uses a descriptive survey design to test research hypotheses and examine relationships between variables. The design collects standardized data from a large sample, allowing for systematic analysis of trends and patterns. The quantitative approach allows for statistical techniques like correlation and regression analysis, identifying key factors influencing mathematics performance.

3.2. Sample size and Sapling Techniques

The population of the study consist of 1600 student at Techiman Senior High School. The students study mathematics as part of their course of study. The school was select due to the fact that, the corresponding author teach at the school selected. The sample size for the study was based on Yamane (1967) sample size determination formula with a total population of 1600. The formula was given as;

$$n = \frac{N}{1 + Ne^2}$$

Where N signified the total population (1600), n signified the sample size and e signified the level of significant (0.05).

$$n = \frac{1600}{1 + 1600(0.05)^2} = 320$$

Based on the formula, the sample size for the study was 320 students.

The study adopted two sampling techniques that is, stratified sampling and simple random sampling. The stratified sampling was used to classified the students based on their course of study. After classified student based on their course of study, simple random sampling was used to select participants from their course of study.

3.3. Questionnaire and Measures

The questionnaire was design based on the constructs under study (peer learning, self-regulatory learning, mathematics interest, and mathematics performance). The measurement items for self-regulatory learning were adopted and modified from the works of Lim et al. (2023). The measurement items for peer learning was adopted and modified from the work of Arthur et al. (2021). The measurement items for mathematics interest were adopted and modified from the work of Arthur et al. (2017). Finally, the measurement items for mathematics performance were adopted and modified form the work of Asare et al. (2024). All the measurement items under their respective constructs were measured using 5-point Likert scale ranges from 1 (strongly agree) to 5 (strongly disagree).

3.4. Data Analysis Procedure

The data analysis for the current study was performed in five different categories. The first category was the descriptive analysis. This was performed to determine the demographic information of the respondents. The second category called the Exploratory Factor Analysis was performed to know the exert number of measurement items loaded strongly at their respective construct with minimum threshold of 0.5. The third category called the Confirmatory Factor Analysis (EFA) was determined whether the measurement items loaded strongly at their respective contracts really fit the model. The fourth category called discriminant validity was to determined what constructs intended to measure, where the square root of the average variance extracted will be compared to the intercorrelated variables. Final, the fifth categories called the paths analysis was executed to answer the research hypothesis whether to accept or reject the hypothesis stated.

3.5. Data Analysis

SPSS (ver. 23) and Amos Graphic (ver. 23) was used to performed the data analysis. SPSS (Statistical Package for the Social Sciences) is a powerful tool for data analysis. To begin, data is first entered into the SPSS Data View, where each row represents a case (e.g., a student) and each column corresponds to a variable (e.g., peer learning, self-regulatory learning, mathematics interest). The Variable View allows for defining the variable names, types, labels, and measurement scales. After data entry, data cleaning processes such as checking for missing values, checking for outliers, and ensuring normality are essential. Key analyses, such as descriptive statistics, correlation analysis, regression analysis, and factor analysis, can then be conducted. For hypothesis testing, the user can navigate to the *Analyze* menu, select the desired test (e.g., Pearson correlation, ANOVA, or regression), and specify the dependent and independent variables. SPSS generates detailed output with tables and charts that summarize key findings, including p-values, effect sizes, and confidence intervals.

Moreover, AMOS (Analysis of Moment Structures) is widely used for structural equation modeling (SEM) to test complex relationships between variables. The process starts by importing data from SPSS into AMOS. In the AMOS Graphic interface, the user can create a path diagram by dragging observed variables (rectangles) and latent variables (ovals) onto the canvas. Arrows are then drawn to depict hypothesized relationships between variables. Next, regression weights, covariances, and error terms are added to complete the model structure. After specifying the model, the user clicks on the *Calculate Estimates* icon to run the analysis. AMOS provides detailed output, including model fit indices (e.g., CFI, RMSEA, GFI), standardized regression weights, and significance levels. These results are critical in confirming whether the hypothesized model aligns with the observed data, making AMOS ideal for examining mediating, moderating, or complex structural relationships. Amos (v.23) was used to performed the data analysis to response to the research hypothese.

3. Results and Discussion

3.1. Results

3.1.1 Exploratory Factor Analysis (EFA)

Exploratory factor analysis (EFA) is a method for reducing the number of variables by counting the latent structures and factors that make up a set of variables (Teoha et al., 2010; Asare & Boateng, 2025). Hu et al. (2018) state that the goal of exploratory factor analysis (EFA) is to identify some of the factors that serve as representations for the measurement variables. As a result, factor analysis is a technique for determining how an entire collection of variables relate to one another rather than for making predictions about variables. By identifying a measure's factor structure, using its data summarizing viewpoint to provide clear insight into interrelationships across variables, and assessing its internal reliability, SPSS (ver. 23) was utilized to estimate the EFA. The loading of each observed variable on its corresponding latent variable was calculated using the EFA. The desired factoring value was 0.5, while the KMO measure of sampling adequacy was .860, which was higher than 0.5 (Table 1). According to Bamfo et al. (2018), this is an exceptional value, demonstrating that there is a strong connection between all of the components.

Table 1
Exploratory Factor Analysis (EFA)

Rotated Component Matrix				
Measurement Items	Component			
	1	2	3	4
Peer Learning (PL)				
PL1			.754	
PL2			.817	
PL4			.826	
PL5			.784	
Mathematics Performance (MP)				
MP3	.814			
MP4	.783			
MP5	.828			
MP6	.858			
MP7	.719			
Self-regulatory Learning (SRL)				
SRL6				.810
SRL7				.799
SRL8				.744
Mathematics Interest (IN)				
MI2		.879		
MI3		.873		
MI4		.883		
MI5		.885		

Table 2
KMO and Bartlett's Test

KMO and Bartlett's Test		
TVE		74.63%
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.877
Bartlett's Test of Sphericity	Approx. Chi-Square	3227.654
	df	120
	Sig.	0.000
Determinant		2.35E-05

The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy (KMO) value of 0.877 is excellent, indicating strong correlations among variables for factor analysis. The Bartlett's Test of Sphericity (TBT) results in a significant correlation matrix with a chi-square value of 3227.654, confirming sufficient structure for factor analysis. The Total Variance Explained (TVE) of 74.63% suggests the extracted factors account for a significant proportion of the data's variance, confirming robustness.

3.1.2 Confirmatory Factor Analysis (CFA)

The major purpose of the confirmatory factor analysis was to determine whether the retained indicator from the EFA results fit the model. Amos (v.23) underwent Confirmatory Factor Analysis (CFA), and the findings are shown in Table 2. It is concluded that our data adequately fit the constructed model using Hair et al.'s (2010) proposed fit indices criterion. The anticipated values for CMIN/DF, CFI, PClose, RMR, RMSEA, and GFI are all less than 3, greater than 0.9, greater than 0.05, less than 0.08, and at least 0.8 respectively. After the analysis, all of these were accomplished. The average variance extracted (AVE), according to Fornell and Larcker (981), is anticipated to be more than 0.5. While also anticipating a composite dependability (CR) of more than 0.7. These results came from the analysis as well. All constructs also had Cronbach's Alpha (CA) values larger than 0.7, as expected (Salkind, 2012). Table 3 presents the Confirmatory Factor Analysis results.

Table 3

Confirmatory Factor Analysis (CFA)

Model fit indices: CMIN; DF; CMIN/DF; TLI; CFI; RMR; RMSEA; GFI; PClose	Estimate
Self-Regulatory Learning (SRL): CA; CR; AVE	
SRL2: I have a special way of solving mathematics questions.	0.836
SRL4: My target in mathematics learning is always achieved.	0.889
SRL5: I always monitor my progress in mathematics learning and understanding.	0.841
Mathematics Interest (MI): CA; CR; AVE	
MI1: I am bored when working on mathematics.	0.906
MI2: I give up easily when working on mathematics.	0.902
MI3: Attending math lessons is exciting for me.	0.873
Peer Learning (PL): CA; CR; AVE	
PL2: Whenever I run into issues with doing arithmetic, I seek for assistance from other classmates.	0.860
PL3: I retain math better while working on a collaborative project.	0.868
PL4: During peer talks in mathematics, I successfully contribute, and my peer accepts it.	0.886
PL5: I get understanding solving mathematics when assisted by peer.	0.861
Mathematics Performance (MP): CA; CR; AVE	
MP3: Without assistance from my math teacher, I am able to answer mathematical problems.	0.792
MP5: My arithmetic performance is fantastic.	0.870
MP6: I can do some arithmetic problems in class on my own, without help from my peers.	0.856
MP7: More than any other topic I study, mathematics is my strongest suit.	0.723

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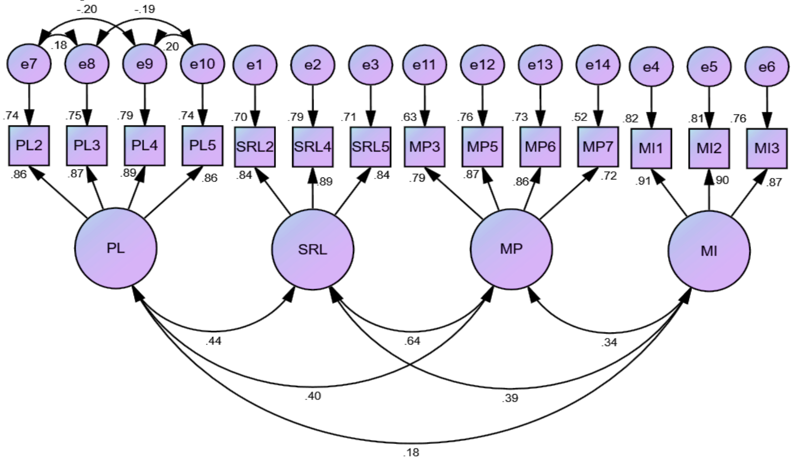
Figure 2
Confirmatory Factor Analysis



3.1.3 Discriminant Validity

The degree to which a new scale's measure correlates with other scales of the same construct is assessed by convergent validity (Trochim & Donnelly, 2006). For convergent validity to be achieved, the least value for AVE must be 0.6 and that of CR must be 0.7 (Dogbe et al., 2020). From Table 3, the lowest value for AVE was 0.660 (mathematics performance) and the lowest value for CR was .885 (mathematics performance). Which indicates that convergent validity has been attained. The study further examines the discriminant validity of the study data. Discriminant validity is calculated by comparing the square root of the Average Variance Extracted (AVE) with the intercorrelated score.

Table 4
Discriminant Validity

Variables	CR	AVE	PL	SRL	MI	MP
PL	.925	.755	.869			
SRL	.891	.732	.441	.856		
MI	.922	.799	.185	.388	.894	
MP	.885	.660	.405	.641	.339	.812

For discriminant validity to be achieved, the least value for the square root of AVE must be greater than the intercorrelated variables (Ko, 2018). From Table 3 the lowest value for the square root of AVES was .812 (Mathematics Performance) which is greater than the highest value for the intercorrelated variable (self-regulatory learning and mathematics performance). This means that discriminant validity has been achieved for the study data.

Table 4 analyzes the course of the numerous direct effects on the study's hypothesis. The path analysis provides a method of separating the association between the different independent variables and the dependent variables, which confirms the hypotheses put forth by previous scholars. The Structured Equation Model (SEM) from Amos (ver. 23) was used to examine the hypothesized paths.

Table 5
Hypothesized Paths Analysis

Direct Effect	Std. Estimate	S.E.	C.R.	*p-value*
PL→MP	.175	.062	2.813	.005
MI→MP	.120	.047	2.552	.011
SRL→MP	.552	.064	8.625	< 0.01

3.2 Discussion

3.2.1 Research Hypothesis 1: Peer learning has a significant effect on mathematics performance.

The first research hypothesis proposed that, peer learning has a significant effect on mathematics performance. The analysis's findings showed peer learning has a direct positive and a statistically significant effect on mathematics performance, with a *p-value* of less than 0.01 (β =.175; CR = 2.813). The outcome demonstrates that using peer learning as a pedagogical tool in mathematics teaching and learning throughout the teaching and learning of mathematics improved performance by 17.5%. Therefore hypothesis 1(H1) which state that, peer learning has a significant effect on mathematics performance was accepted for the current study. The current study finding support the findings of Lim et al. (2023). Their study was performed with the used of 347 respondents using structural equation modelling to examine the effect of peer learning and self-regulatory on academic achievement. the result from their study found that, peer learning had a significant effect on their academic achievement. Moreover, Boadu et al. (2023) examined the effect of peer tutoring on 350 students in Kumasi senior high school and Kumasi academic senior high school academic achievement as moderated and mediated by motivation and teacher quality. Their result support the current study result that, peer tutoring had a statistically significant impact on students' academic achievement. In a similar vein, Arthur et al. (2022) used purposive and convince sample techniques to sample 373 first year undergraduate students of Akenten Appiah Menka University of Skills Training and Entrepreneurial Development to determine whether students' performance in mathematics can be enhanced through motivation, peer assisted learning, and teaching quality as mediated by their mathematics interest. The result from their study found that, peer assisted learning had a statistically significant effect on student performance in mathematics which support the findings of the current study.

3.2.1 Research Hypothesis 2: Self-regulatory has a significant effect on mathematics performance.

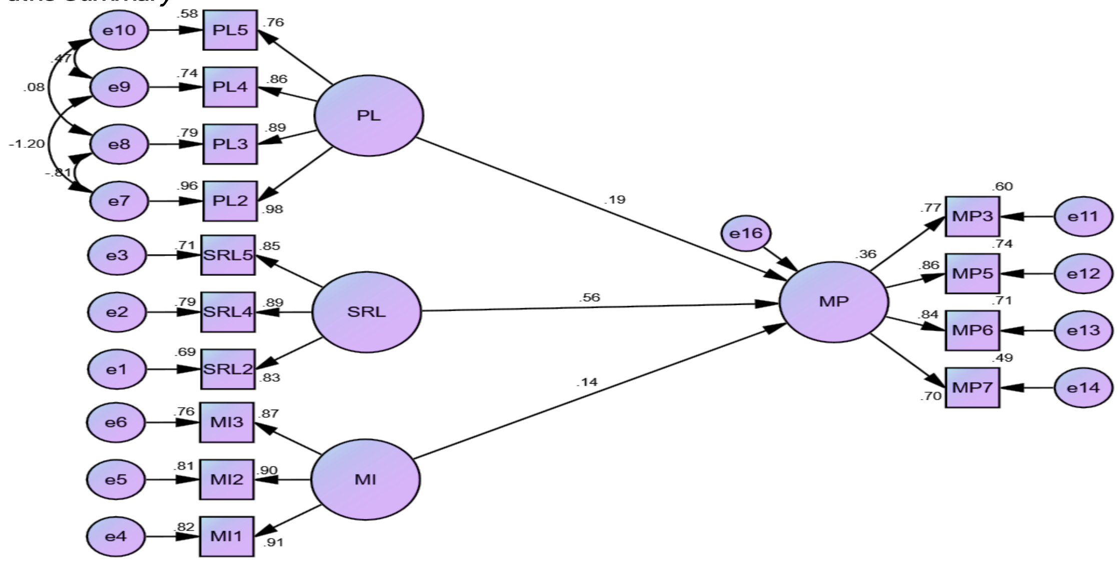
The second research hypothesis proposed that, self-regulatory has a significant effect on mathematics performance. The direct effect of self-regulatory learning on mathematics performance as presented in Table 4 shows that the direct effect of self-regulatory on mathematics performance was positive and statistically significant with a *p*-value less than 0.01 (β = .552; CR = 8.625). There was a 55.2% effect on mathematics performance which was influenced by self-regulatory learning among students. Therefore, hypothesis two which state that, self-regulatory has a significant effect on mathematics performance was accepted for the current study. The current result is in conformity with studies such as Lim et al. (2023). Their study was performed with the used of 347 respondents using structural equation modelling to examine the effect of peer learning and self-regulatory on academic achievement. the result from their study found that, self-regulatory learning had a significant effect on their academic achievement which is in line with the current study result.

3.2.3 Research Hypothesis 3: Mathematics interest has a significant effect on mathematics performance (H3).

Moreso, the third research hypothesis proposed that, mathematics interest has a significant effect on mathematics performance. Table 8 displays the findings of the analysis of the effect of mathematics interest on mathematics performance. With a *p-value* of less than 0.05 (β =.120; CR = 2.552), the data shown in Table 8 indicates that mathematics interest had a direct positive impact on mathematics performance. According to the analysis's findings, mathematics interest had a 12% favorable impact on students' mathematics performance. Therefore, hypothesis three which state that, mathematics interest has a significant effect on mathematics interest was accepted for the current study. The current result confirmed with previous studies such as Bright (2024). Examined the effect of using technology in teaching and learning mathematics on students' mathematics performance as mediated by student mathematics performance using 216 students selected from three senior high schools in Kumas through simple random sampling. The result from their study found that mathematics interest had a significant effect on student's mathematics performance which support the finding of the current study. In a similar vein, Asare et al. (2023) explored the moderating role of students interest on the impact of ChatGPT on students mathematics performance with a sample 250 BSC. Mathematics Education and BSC Information Technology students at Akenten Appiah Menka University of Skills Training and Entrepreneurial Development (AAMUSTED). The result from their study found that, student interest positively moderates the connection between ChatGPT used on mathematics performance. Their study results also found that, students' interest in mathematics had a significant impact on student mathematics interest. Moreover, Asare et al. (2024) in their study on the impact of classroom management, teacher quality, and mathematics interest on mathematics achievement with a sample size of 285 students found that, student mathematics interest had a significant impact on their mathematics achievement. In conclusion, Arthur et al. (2017) in their study found that, the only variable that significantly predict student mathematics achievement was their interest in mathematics learning.

Figure 3

Paths Summary



4. Conclusion

Based on the 320 students selected from Techiman Senior High School, peer learning had a positive and statistically significant effect on mathematics performance. Moreover, self-regulatory learning had a positive and statistically significant effect on mathematics performance. Finally, mathematics interest had a positive and a statistically significant effect on mathematics performance. The research's scope was restricted to Techiman Senior High School. This school is not sufficiently representative of the study population to allow for meaningful conclusions to be drawn, subsequent research must explore the impact of employing more than two senior high schools with Techiman. Additionally, the only method of gathering data from the students in this study was a questionnaire. Future research must employ interviews to investigate how students perceive the impact of using peer assisted learning as a teaching and learning strategy on their performance in mathematics, as well as the importance of self-regulatory learning in mathematics education.

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