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Research Article

Improving STEM mathematics achievement through self-efficacy, student perception, and mathematics connection: The mediating role of student interest

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Science, technology, engineering, mathematics (STEM) education, the current engine for this technological generation, has made its way into Ghana's education system and is progressively becoming autonomous, particularly at the senior high level. It depends extensively on student mathematics performance to progress into their various dream STEM career programs. It is worthwhile to study the relationships between STEM students' mathematics (perception, self-efficacy, and connection) and mathematics achievement with their study interest mediating between them. The researchers purposively and conveniently sampled 385 general science respondents from eight selected senior high schools in the Kumasi metropolis for this study. The study produces results by quantifying and analyzing the collected data by investigating the six distinct hypotheses with structural equation model (SEM) using SPSS (26) and AMOS (24) software to confirm or refute fundamental assumptions. The study suggests that general science students' mathematics self-efficacy and connection directly impact their mathematics performance and, at the same time, somewhat mediate their ability to perform well in mathematics through their study interest. Moreover, there was no relationship between mathematical perception and student interest or achievement. Students must continue to evaluate the efficacy of their learning tactics to achieve academic excellence, and they must make reliable and self-efficacious evaluations of their mathematical learning as well as their mathematics connections to other STEM subjects to improve their study interest and mathematics achievement. The study recommends that stakeholders, curriculum developers, and implementers of the new STEM curriculum try to connect mathematics to all aspects of STEM as much as possible to either directly improve their performance or increase their interest in improving their mathematics education.

Keywords: STEM; Self-efficacy; Mathematics connection; Study interest; Mathematics achievement

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1. Introduction

Mathematics has been inextricably linked to human daily existence since time immemorial and continues to play an important role in educating students about daily life activities to this day (Kanbolat et al., 2011). In light of the advancement of futuristic mathematics and its implementation in all fields of science, technology, and engineering since 1960, the impact of mathematics has grown in both our daily lives and the scientific world (Kanbolat et al., 2011). Given the technological era we live in, it is critical for students and teachers to fully comprehend the significance and relevance of mathematical education and how it can be embraced.

In recent decades, science education reformation initiatives have aimed at assisting students in acquiring a broader and deeper knowledge of scientific ideas and thinking, and enhanced scientific problem-solving skills rather than merely memorizing facts and formulas (Brown et al., 2016). As a result, numerous governments are attempting to devise solutions to ameliorate the situation (Appiah et al., 2022; European Commission, 2015).

In Ghana, (Science, Technology, Engineering, Mathematics) STEM education has emerged as a critical component in augmenting the traditional general science programs in secondary schools to improve the education system. However, general science programs in Ghanaian secondary schools continue to supplement most STEM activities, such as the National Math and Science Quiz (NMSQ), STEM Festival, Robotics Inspired Science Education (RiSE) competition, and Renewable Energy Challenge, to name a few, and have been the recruiting stage for various STEM career programs at the tertiary level.

Creative innovation and technical growth through STEM education development are undeniably dependent on the modern world's restrictions on improving human quality of life and environmental protection (European Commission, 2015). Nonetheless, reports reveal that student interest in general science learning is declining as a result of an unsatisfactory percentage of students studying STEM subjects to meet society's future demands (Kelley & Knowles, 2016). The pioneers of STEM education, the US education system, for example, is attempting to expand the number of students who choose STEM education, as well as the employment and career in STEM disciplines, and to enhance the STEM capacity of students, including those that are not enthusiastic about pursuing STEM fields (Popa & Ciascai, 2017).

Students' enthusiasm for science, technology, and engineering must be fueled primarily by a strong interest, in addition to other factors that improve mathematics achievement, to increase their chances of getting admission to the STEM education system (Reardon et al., 2009). This is surprising asserted by many researchers (Adetunde, 2009; Appiah et al., 2022; Jurdak et al., 2016; Stinson, 2004) that mathematics is widely used around the world as an essential part of the filtration system for students who seek admission to institutions of higher learning. As a result, it is critical for students, particularly those studying in STEM fields, to develop a good repertoire of pedagogical approaches earlier in their education journey (Blackmore et al., 2021). In essence, policymakers and politicians place a high value on mathematics at all levels of the Ghanaian education system, making it an entry-required subject into senior high schools, colleges of education, polytechnics, and universities (Denteh et al., 2017).

In light of this, students' mathematical achievement has recently been a topic of discussion, with educators attempting to determine the causal effect of student mathematical achievement at all levels, particularly in senior high school (Appiah et al., 2022). However, the mathematics achievement of STEM students in senior high school remains to be investigated based on their self-efficacy, mathematical connection to other subjects and fields, and perception of mathematics as mediated by student study interest using the structural equation model (SEM).

2. Background

2.1. Self-Efficacy Impact on Mathematics Achievement

Academic self-efficacy is defined by Zimmerman (1995) as subjective judgment of one's ability to mobilize and implement courses of activity to achieve specified types of educational achievements. According to Usher and Pajares (2008), the literature on self-efficacy stems from Albert Bandura's work from the 1970s, with most of today's modern knowledge coming from the fields of psychology. Bandura's legendary masterpiece in synthesizing several research findings into a coherent framework while incorporating social learning theory and self-efficacy mechanisms in human agency extends the theory's implications for organizations, groups, societies, and political bodies to chart a course for future research (Bandura et al., 1999). Many researchers have looked at self-efficacy in several different contexts as feasible, such as occupational functioning and achievement, educational experience, and programming results (Appiah et al., 2022; Callaman & Estela, 2020; Li et al., 2020; Xiao & Song, 2022).

Students' self-efficacy is broadly acknowledged as both a causative agent and an influence on academic achievement (Schöber et al., 2018). Significant positive relationships were found between students' overall academic accomplishment and effort, self-efficacy, and general drive (Aida & Ali, 2009). Blackmore et al., (2021) in their review assessed self-regulated learning with a focus on Zimmerman's model, self-efficacy assessment, and how students may break the vicious cycle of bad learning with a concentration on STEM.

Trujillo and Tanner (2014) found academic achievement, self-regulated learning, and resilience have all been found to be mediated by self-efficacy. Schöber et al. (2018) and Liu and Koirala, (2009) also discovered, using structural equation modeling, that self-efficacy had a beneficial impact on subsequent mathematics achievement due to very high achievement and self-efficacy stability. However, self-efficacy is argued and demonstrated to be domain-specific, which means that having strong self-efficacy in one field does not necessarily translate to a related subject (Callaman & Estela, 2020). Self-efficacy research seeks to answer the question, "To what extent do people's perceptions of themselves influence their actions?" (Trujillo & Tanner, 2014). According to Bandura et al. (1999), it is simpler to maintain a sense of effectiveness, especially when dealing with obstacles, when significant persons express confidence in one's talents rather than expressing concerns. McConnell et al. (2010) also indicated that students with low self-efficacy but good academic backgrounds obtained the same grades as those with high self-efficacy but with lower academic backgrounds.

Zhang et al. (2022) found self-efficacy to be essential in supporting an individual student's STEM career choice. Flowers and Banda (2016) contend that self-efficacy, especially about the progress of science authenticity, is an important and understudied section of the STEM achievement challenge for disadvantaged students. Self-efficacy influences individuals' goal selection, effort exerted to achieve those goals, and persistence when challenges arise. As self-efficacy is a major predictor of task motivation and achievement, on average, those with high STEM self-efficacy outperform and stay longer in STEM fields than those with low STEM self-efficacy (Bandura & Locke, 2003).

2.2. Perception of Mathematics' Impact on Achievement

Henry (2012) revealed that the association between perception and achievement is stronger in young learners with lower cognitive abilities. According to the findings of Vukovic et al. (2013), mathematics anxiety is an important construct to examine when investigating the roots of individual differences in early students' arithmetic ability. Wen and Dube (2022), called for an urgent need to enhance students' mathematical perceptions because a substantial proportion of students' perceptions toward mathematics decline significantly during secondary education. Dowker et al. (2016), on the other hand, believe that mathematics anxiety is more connected with achievement in older students than in younger ones. Students' perceptions reflect nearly 9% of student's interest in mathematics, demonstrating a negative significant relationship between student perception and their interest in mathematics (Arthur et al., 2017).

There have been many beliefs among students regarding the difficulty of mathematics, which have intimidated many students throughout their educational pursuits (Arthur et al., 2017). Because these perceptions are unfavorable beliefs held by students, many students have low self-concepts in mathematics (Oluwafunmilayo, 2013). According to Siegle et al., (2014) and Winheller et al., (2013), students' perceptions of mathematics are influenced not just by their teachers' and students' attitudes but also by the environment in which they study. Arthur et al. (2022) discovered that students' mathematics-studying interests moderated the links between mathematics-studying motivation and achievement. Middleton and Spanias (1999) see mathematics as having a strong impact on motivation to solve real-life challenges. Skaalvik et al. (2015) discovered that the relationships between students' academics and motivation are partially mediated by psychological encouragement and self-efficacy.

2.3. Impact of Mathematics Connection on Achievement

Mathematical connections are the relationships between mathematical topics and other disciplines, as well as their importance to the real universe or everyday life in an attempt to make students comprehend mathematics topics and deal with problems (Ferrini-Mundy, 2000). García-García and Dolores-Flores (2018) defined mathematical connections as a cognitive process whereby individual links two or more concepts, ideas, theorems, definitions, representations, meanings, and processes among themselves, with other fields, or with the real world. According to Sari and Karyati (2020), students are much enthused by the interconnectedness of mathematical parts as a unit of knowledge, which provides them with a deeper comprehension of the motivation of whatever they acquire and allows them to look at the topics of the mathematics world in general.

Sari and Karyati (2020) propose that students' mathematical connection abilities should be developed in school to improve students' interest and mathematical knowledge growth. Menanti et al. (2018) discovered an improvement in students' mathematical connection ability by employing a practical mathematics education development based on the learning tools. Many factors contribute to students' lack of mathematical connection skills when studying mathematics, a few being their inability to integrate previously taught mathematics ideas with fresh ones and, most often, they are unable to link their memorization of ideas to their interpretation (Menanti et al., 2018).

2.4. Student Study Interest

Rogan and Schmidt (2017) asserted that student interest is an important factor in cognitive growth and learning and that there is a positive association between both mathematics interest and achievement. Recent research reveals that students who have stronger interests possess stronger self-efficacy, indicating a good association with mathematics achievement (Pietsch et al., 2003). Aguilar et al. (2016) found that students' perceptions, interests, and ideas regarding mathematics education are based on prior cognitive and affective experiences. Cognitive representations are relevant from a reasoning point of view, while attitudes, sentiments, interests, and emotions are relevant from an affective domain. According to Gadanidis (2012), students around the world have largely negative perceptions and misconceptions about mathematics achievement, although they might have an interest in studying the subject. Furthermore, Lent et al. (1991) discovered that student potentials did not add positive significant variability to the forecasting of mathematics interest after managing self-efficacy. In other words, self-efficacy has a significant influence on the connection between mathematics achievement and interest.

Theoretically, Bandura (Bandura, 1977, 1986; Bandura et al., 1999; Bandura & Locke, 2003) contended that a learner who has a high degree of self-efficacy can better manage his learning activities and decrease student perceptions. According to Bandura's social learning theory, mathematics anxiety can be attributed to a lack of mathematics self-efficacy. In other words, it is postulated that interest in mathematics is related to self-efficacy, which is linked to mathematics perception and achievement (Zhang & Wang, 2020).

Although their explanatory analysis results disclosed their comparative interest in mathematics, Wong and Wong (2019) found that student interest was not highly associated with achievement. Given the substantial relationship between interest and achievement, Wong and Wong (2019) emphasized the necessity of activating interest among students with relatively low mathematics achievement. Pantziara and Philippou (2015) discovered that students' mathematical interests and achievement were influenced by self-doubt, self-efficacy beliefs, and achievement goals when addressing motivation and the degree to which it affects students' mathematical achievement and interest.

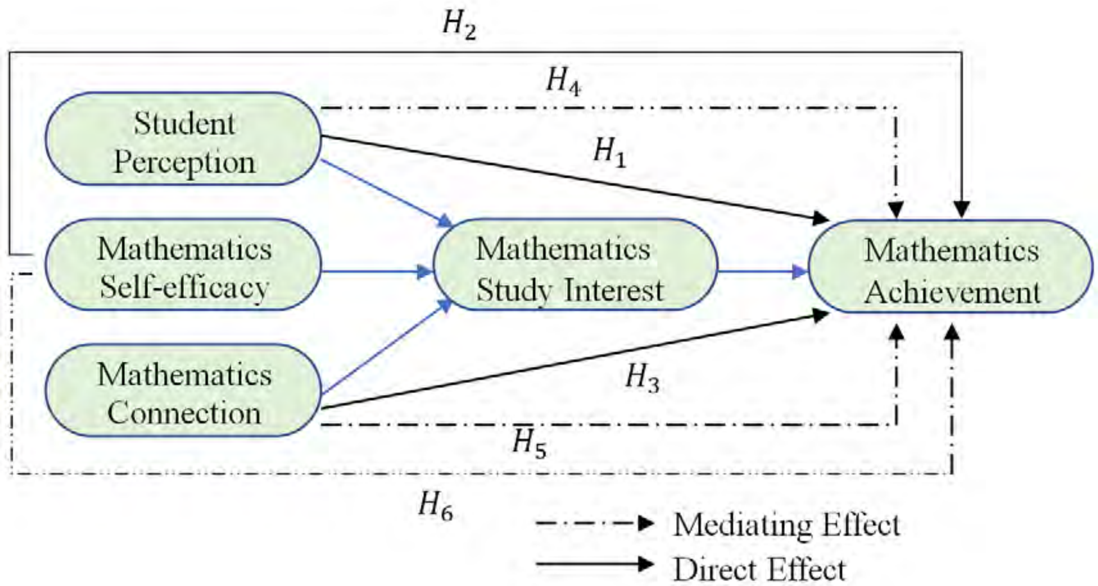
Few studies, however, have investigated the relationship between students' perceptions, mathematics self-efficacy, and their connection to mathematics with their interest contributing to better mathematical achievement within a mediation model. Even though some of these factors have been somewhat carried out in many parts of the world, they need to be introspectively researched in Ghana, where we are on the verge of introducing STEM education. Thus, we will clarify the interlinkages and provide empirical evidence between SHS general science students' self-efficacy, student perception, mathematical connection, student interest, and mathematics achievement in this study.

3. The Objective and Research Hypotheses

The current study tackles these constraints by investigating the relationships between STEM students' mathematics (perception, self-efficacy, and connection to other related STEM subjects) and academic achievement. More particularly, it analyzes how a single variable of study interest mediates multiple dimensions of STEM students' mathematics (perception, self-efficacy, and connection) and mathematical achievement. As a result, the study will contribute to current research by measuring not only the direct influence of perception, self-efficacy, and connection on student achievement but also the process by which perception, self-efficacy, and connection connect with academic achievement via study interest.

More specifically, there are six distinct sets of relations the current study seeks to explore as shown in the conceptual framework of the study.

Figure 1
Conceptual Framework



In conclusion, based on these study gaps, the following research hypothesis will be addressed:
H1: Student Perception (SP) has a direct positive effect on Mathematics Achievement (MA).

H2: Student Mathematics Self-Efficacy (MSE) has a direct positive effect on Mathematics Achievement (MA).

H3: Student Mathematics Connection (MC) has a direct positive effect on Mathematics Achievement (MA).

H4: Students' interest in mathematics (MSI) mediates the relationship between Student Mathematics Self-Efficacy (MSE) and Mathematics Achievement (MA).

H5: Students' interest in mathematics (MSI) mediates the relationship between Student Perception (SP) and Mathematics Achievement (MA).

H6: Students' interest in mathematics (MSI) mediates the relationship between Student Mathematics Connection (MC) and Mathematics Achievement (MA).

4. Method

4.1. Research Design

The researcher produces results by quantifying and analyzing factors by focusing on the collection of measurable and analyzable data by investigating hypotheses or research questions with statistical techniques to confirm or refute fundamental assumptions (Williams, 2007). It entails the use and analysis of numerical data through the application of specific statistical techniques to answer the study objectives.

4.2. Participants

Kumasi, the capital of the Ashanti Region, is bestowed with great senior high schools that are actively involved in STEM education in addition to the general science programs that they provide to students. For instance, Prempeh College, a Kumasi school, won the 2019 Ghana's Robotic Academy Foundation Competition, the Robofest World Championship in the same year in Michigan, U.S.A. (Boateng, 2020), and the 2021 National Math and Science Quiz. Several schools in Ashanti Region have also excelled in STEM-organized competitions, making the region a suitable area for this study. This prompted the researcher to select general science students from eight public schools in Ghana's Ashanti Region's Kumasi Metropolitan Area. The Kumasi metropolis has about 10,000 general science students population. The selected schools such as Opoku Ware School alone has twelve forms of one science classes, not to mention the other forms and classes in Prempeh College, Yaa Asantewaa, Kumasi Anglican, St Louis, Asanteman, Kumasi Adventist, and T. I Ahmadiyya, where data was conveniently obtained from students in form one to three. Convenient sampling was the most effective technique to collect data from science students during their accessible periods, as SHS one (K-12) and three (K-14) were in session and SHS two was just getting back from break.

According to Uakarn et al. (2021), the sample size is defined in quantitative research as the depiction of the selected study population for the researcher to gather data for analyzing descriptive and inferential statistics. Taro Yamane's sample size formula as used by Arthur et al. (2022) was adopted by this study as follows: $= \frac{N}{1+N(e^2)}$ where $n = sample\ size$, $N =$ population size $= 10{,}000$, $e =$ margin of error or reliability level 95% or; e = level of precision always set the value of 0.05. This implies that $n = \frac{10000}{1+10000(.05^2)}$, $n = \frac{10000}{26} = 384.6154 \approx 385$.

The resulting sample size of 385 appears to agree with the research findings of Wolf et al. (2013), which brought to light a range of sample size limits for structural equation modeling (SEM) (i.e., from 30 to 460 cases), emergent themes of association with both parameters and sample size, and illustrates the restrictions of frequently cited standards.

According to Bernard (2006), purposeful sampling happens when a researcher decides what information should be underlined and then seeks to identify people who are prepared to supply the information to the greatest of their ability or capabilities. The metropolis, schools, and general science programs were chosen for this study using a purposive sample strategy. A convenient sampling strategy was utilized to pick 385 general science students from senior high schools in

Ghana's Kumasi Metropolis that are actively interested in STEM teaching and competitions to participate in this study. Two of the 385 potential functional participants were taken out from the final analysis because of insufficient data entry, resulting in a 99.0% rate of responses. As a consequence, the study's final sample size is 383 (240 males and 143 females), virtually evenly drawn from forms 1 to 3 (35.8%, 32.4%, and 31.9%). Male respondents outnumbered female respondents by 15.4%. The majority of respondents polled (62.7%) attended mixed-sex schools, with the remainder attending boys-only schools (22.7%) followed by girls-only schools (14.6%). Although the minimum age to graduate from SHS is eighteen years, 1.3% of respondents were beyond the age of 23, with the majority (55.6%) being between the ages of 17 and 19, followed by 14-16 years (31.1%), and only three (0.8%) being under the age of 13 (see Table 1).

Table 1
Demographic Statistics

Measure and Category	*N*	*Percent (%)*
Form		
Form 1	137	35.8
Form 2	124	32.4
Form 3	122	31.8
Gender		
Male	240	62.8
Female	143	37.2
Age		
Below 13 yrs	3	0.8
14 - 16 yrs	119	31.1
17 -19 yrs	213	55.6
20 -22 yrs	43	11.2
Above 23 yrs	5	1.3
School Type		
Boys Only	87	22.7
Girls Only	56	14.6
Mixed	240	62.7

4.3. Instrument

Based on the literature study, the research questionnaire was designed with 34 items divided into two sections. The first component, which included the form, gender, age, and school type, was used to collect the students' demographic information. The subsequent section has six question items for each of the study's five constructs. The majority of these items are based on Appiah et al. (2022), Arthur et al. (2022), Zhang and Wang (2020), Zhou et al. (2020), and Trujillo and Tanner (2014). Three independent variables (perception, self-efficacy, and connection), one mediator (study interest), and one dependent variable (achievement) were used in this study. To assess each item in this section, a five-point Likert scale spanning from strongly disagreed (1) to strongly agreed (5) was utilized. Unclear phrases in the questionnaire were found and rephrased in a pilot survey before the final version of the questionnaire was utilized for data collection. An online questionnaire was used to address the issue of dispersed participants. From start to finish, all participants' data was assured to be private and secure. The researcher outlined the study topic, the aim of the data, and the distinct approach to answering it at the onset of the questionnaire. The respondent was required to meet the accompanying main requirements: (1) Be a general science student currently enrolled in a Senior High School in the Kumasi Metropolis; (2) Understand and be able to respond objectively and honestly to questions relating to their mathematics study. The researchers used the months of August and September 2022 to collect data to get in touch with all three student levels. The online survey was sent using the Google survey tool in this investigation.

In addition to tablets, the researcher personally delivered hard paper questionnaires to the selected schools for data collection.

4.4. Data Analysis

Microsoft Office Excel 2019 was used to access the uploaded online survey data and also code the hardcopy questionnaires. It was then imported into IBM-SPSS 26 for exploratory factor analysis (EFA), followed by IBM-AMOS 24 for confirmatory factor analysis (CFA).

The EFA, which tries to work on inter-related factors, produced a KMO statistic of 0.902, which is significantly higher than 0.5 for the required factor value, as indicated by Hair et al. (2014). A KMO score larger than 0.80, according to Kaiser's (1974) research, is more compatible with component analysis, indicating a significant link among the items. With a Chi-square score of 8448.476 and 435 levels of freedom, Bartlett's sphericity test proved significant. A significant p = 0.000 less than 0.001 Bartlett's test suggests that there is a sufficient correlation to support factor analysis. The five components gave cumulative squared loadings of the rotation sum of 66.37% of the total variation explained. The rotating varimax technique was used to reduce the number of complex parameters while increasing the average yield. According to Kimberlin and Winterstein (2008), the internal consistency of an instrument's measuring scale is critical for determining the capability of items employed in the instrument. The rotated component matrix loaded five observed measurement items for self-efficacy, six each for students' perception, mathematics connection, and study interest, and four for student achievement.

Cronbach alpha for the entire items is .901 and values for the constructs obtained from the rotated component matrix were SP (.933), MSE (.809), MC (.918), MSI (.917), and MA (.901) all have alpha values better than 0.6, indicating a strong link between the components (Tavakol & Dennick, 2011). The rotated component matrix allowed the researcher to examine and determine which item(s) that should be retained or deleted before running a CFA on the constructs using AMOS-24 software.

5. Process

5.1. Validity and Reliability Analysis

CFA allows researchers to test their hypotheses concerning the existence of a link between the components studied and the load factor as stipulated by (Lahey et al., 2012). The CFA was directed to validate the metrics adopted during the EFA and also attempt to validate a hypothesis before using an analytical diagram to identify the latent and construct variables. One of the typical modifications to optimize the CFA model was the removal of items with factor loadings less than 0.50. After the CFA process, the observed variables were reduced to three measurement items each for self-efficacy, students' perception, and mathematics connection; four for student achievement; and retained all six variables for study interest.

The Cronbach Alpha (CA) was run for the retained observed variables using SPSS (v26) to access the internal consistency between the measurement items. All the five latent constructs recorded a CA greater than 0.7 (see Table 2), achieving internal consistency among their respective items as recommended by Tucker (1955).

It is gratifying to establish convergent, and reliability authenticity in the model since the Composite Reliability (CR) was greater than the Average Variance Extracted (AVE), and the Maxi Shared Variance (MSV) was less than AVE for all observed variables, meeting the commensurate threshold values of CR of at least 0.7 and AVE of at least 0.5 as presented by Fornell and Larcker (1981).

According to the findings, self-efficacy had the lowest AVE (.510) and CR (.805), whereas perception and achievement had the greatest AVE (.703) and perception had the highest CR (.934). (see Table 3). The discriminant validity was evaluated using the Fornell and Larcker, (1981) method, which involved comparing the squared root of the AVE with the inter-correlation scores.

Table 2
Confirmatory Factor Analysis

Label	*Item*	*Std. Factor Loading*
Model Fit Indices: CMIN=608.685, DF=285, CMIN/DF=2.136, RMR=.133, TLI=.952, NFI=.924, IFI=.958, CFI=.958, IFI=.958, RMSEA=.055, PCLOSE=.105		
Students' Perception (SP): CA=.933		
SPI	My perceived opinion about mathematics affects my overall mathematics achievement.	.855
SP2	Many formulae in mathematics make learning harder.	.907
SP3	I find that mathematics helps me improve my reasonable thinking and logical argumentation.	.896
SP4	Mathematics helps me to understand the world around us.	.799
SP5	Teachers and other students' attitudes toward mathematics have a positive impact on my perceived opinion of mathematics.	.871
SP6	Studying ahead of the class makes mathematics learning in the classroom very easy.	.683
Students' Mathematics Self-Efficacy (MSE): CA=.799		
MSE2	I am confident in my ability to solve mathematical problems in science, technology, and engineering.	.635
MSE3	I have the necessary skills and abilities to learn mathematics.	.807
MSE4	I am concerned that the other students are better at mathematics	.711
MSE5	I contribute effectively and my peers accept my contribution during lessons	.691
Mathematics Connection (MC): CA=.918		
MC1	Mathematics establishes the need to gain knowledge, and apply skills to answer questions	.928
MC2	I am inspired to master mathematics since it applies to many aspects of life.	.867
MC3	Mathematics is filled with interesting notions that appear to exist independently of human activities.	.879
MC4	Mathematical ideas and methods can be tested and applied in science, technology, and engineering.	.779
MC5	Mathematics aids in connecting concepts with real-world circumstances.	.658
MC6	Mathematics assists me in developing innovative ideas based on alternatives and new ideas based on established ones.	.625
Mathematics Study Interest (MSI): CA=.917		
MSI1	I am interested in studying mathematics as part of my course.	.966
MSI2	Mathematics is one of my favorite subjects to study.	.959
MSI3	I like my private studies the best when I am studying mathematics.	.865
MSI4	I am always keen to join in group discussions about mathematical problems.	.593
MSI5	I frequently look for opportunities to learn new abilities for tackling mathematical problems.	.679
MSI6	I tried persistently to solve mathematics questions even if I failed.	.648
Mathematics Achievement (MA): CA=.901		
MA1	I always accomplish my mathematical task.	.874
MA2	My mathematics achievements help me make better decisions.	.901
MA3	My mathematics achievements improve my analytical skills.	.893
MA4	I perform better and obtain good scores in mathematics courses.	.664

According to Olu et al. (2021), the least √AVE should be greater than the maximum association score to obtain discriminant validity. The study demonstrated discriminant validity by obtaining the lowest √AVEs of 0.714 for self-efficacy, which was greater than the highest correlation score for achievement.

Table 3
Model Validity Measures

	CR	*AVE*	*MSV*	*MaxR(H)*	*Self efficacy*	*Perception*	*Connection*	*Study Interest*	*Achievement*
Perception	0.934	0.703	0.154	0.945	0.839				
Self-Efficacy	0.805	0.510	0.113	0.817	0.337***	0.714			
Connection	0.911	0.636	0.379	0.940	0.393***	0.183	0.797		
Interest	0.911	0.639	0.379	0.968	0.228***	0.211	0.616***	0.799	
Achievement	0.903	0.703	0.209	0.924	0.127*	0.230***	0.400***	0.457***	0.839

Note. *** p <.001.

Following the alteration, the general model predicts very good indices that correlate to the values of their respective standard indices. As demonstrated in Table 3, a Chi-square of 608.685 with 285 degrees of freedom yielded a very acceptable CMIN/DF of 2.136, less than 3 as recommended by Hair et al. (2009).

Furthermore, the Root Mean Square Residual (RMSEA) demonstrated a good match of 0.055 less than 0.08 for the essential factors of the five observed variables to be legitimate and acceptable, as advised by Chen, (2007) and Marsh et al., (2004) to have a deviation of the hypothesized model from a better match. The p-close (0.105>0.05) was well accomplished, as Hair et al., (2009) indicated, to be statistically insignificant at 5%. As suggested by Hatcher and Stepanski (1994), Cangur and Ercan (2015) and Byrne (2001), for the fit indices to display impressive model fit indices of more than 0.90, the CFI (0.958), NFI (0.924), RTI (0.913) and IFI (0.958) fit indices were well achieved (See Table 3). The Tucker-Lewis Index (TLI) incremental fit index (0.951) was greater than 0.90, meeting the suggestion of Ding et al. (1995).

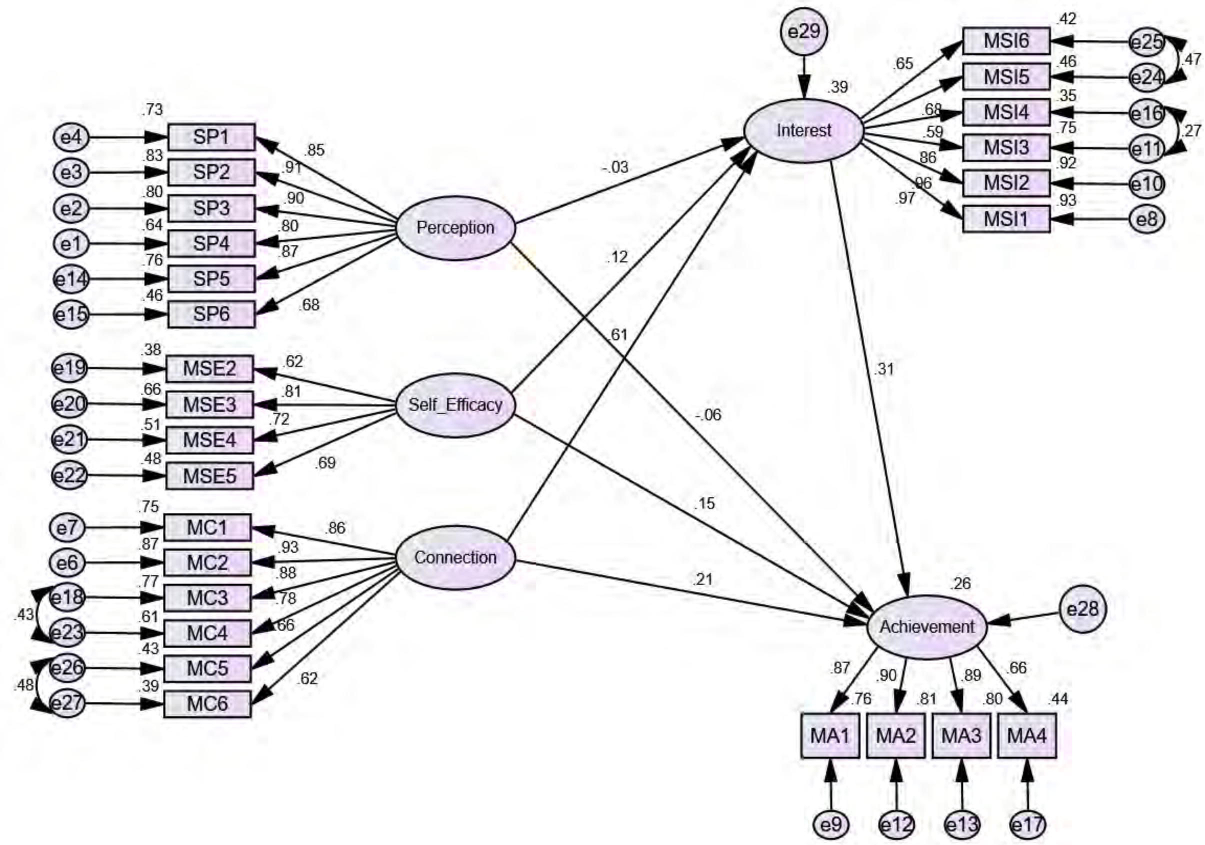
5.2. Structure Equation Model

In AMOS (v24), the researchers build a structural equation model (shown in Figure 3) by aligning perception, self-efficacy, and mathematical connection as independent factors; students' achievement or achievement as the dependent variable; and study interest as the mediating variable. Structural equation modeling was conducted to test hypotheses regarding (a) the relationship of the respective dependent variables (perception, self-efficacy, and mathematical connection) on student achievement and (b) the mediating effect of study interest among the respective dependent variables (perception, self-efficacy, and mathematical connection) on student achievement. These variables were assessed in a structural equation model with a 5,000 bootstrap sample and a 95% confidence level using the Bias-Corrected (BC) percentile method of bootstrapping. The structural equation model, like the CFA in tables 2 and 3, met the various fit indices proposed (see Table 4).

6. Results

At the 0.05 level, the direct (unmediated) effect of self-efficacy on achievement is substantially different from zero at the 0.01 level ($p = .010$; $\beta = -0.248$; CR = 2.770). When perception increases by one, student achievement decreases by 0.073, and the direct effect of perception on achievement is non-significant at the 0.05 level with 1.271 standard errors below zero ($p = .238$; $\beta = -0.073$; CR = −0.1.271). The results on the hypothesized paths also indicate that mathematics connections have a direct positive effect on student mathematics achievement. That is, the standardized direct

Figure 2
Structural Equation Path



effect of the mathematics connection on student achievement is 0.191 with 3.234 standard errors above zero (p =.003; β = 0.191; CR = 3.234). This is a bootstrap approximation derived from the construction of a two-sided bias-corrected 95 % confidence interval. Hence, hypothesis H1: student perception has a direct positive effect on mathematics achievement was not supported. However, H2 accepts student mathematics self-efficacy to have a direct positive effect on students' achievement in mathematics and also H3: student mathematics connection has a direct positive effect on mathematics achievement was thus supported (see Table 4).

Table 4
Mediation Effects Bootstrap Analysis

Analysis Path	*Effect*			*Std Est.*	*CR*	*95% CI of Indirect Effect*	
	Total	Indirect	Direct			Lower	Upper
Perception – Achievement	.238	.535	.286	−.073	−1.271	−.042	.020
Self -Efficacy – Achievement	.004	.013	.010	−.248	2.770	.007	.076
Connection – Achievement	.000	.000	.003	.191	3.234	.112	.274
Model Fit Indices: CMIN=700.223, DF=288, CMIN/DF=2.431, RMR=.284, NFI=.913, RFI=.901, TLI=.940, IFI=.947, CFI=.946, RMSEA=.061, PCLOSE=.001							

Note. Bias-corrected percentile method; 5,000 Bootstrap sample; 95% confidence Level; p-value sig. at 1%.

6. 1. Mediating Effect

The study also examined how students' academic interests mediate their perception and achievement, self-efficacy and achievement, and connection and achievement. The p-value of the total (direct and indirect) effect of student perception on achievement is not significant (p =.238), and at the same time, the standardized indirect (mediated) effect of perception on achievement is also not significantly different from zero at the 0.05 level (p =.535 two-tailed). It was also found that zero falls within the path coefficient of the indirect effect's 95% confidence interval (−0.042 and 0.020), making it non-significant, and therefore, hypothesis H4 should be considered to exhibit no relationship with the mediation.

7. Discussion

Previous research on mathematics students' (self-efficacy, perception, and connection) on their achievement through study interest has generally concentrated on all levels of education, with little consideration given to the new emergent STEM education within the secondary schools' general science program. As a result, this study contributes to the literature on mathematics students' learning motivation in STEM education. The study adds to existing research by demonstrating potential paths that increase student progress. Several of the paths are of specific interest.

The ages of the students were not taken into account in the path analysis to determine the impact on their achievement because the majority of them are between the ages of 14 and 19, which is the ideal age for entering senior high schools in Ghana to commence comprehensive general science programs.

Students who perceive their self-efficacy positively and thus have greater confidence in their academic ability in mathematics tend to positively impact their mathematics achievement in one pathway. This implies that there is about a 5.3% improvement in students’ mathematics achievement when students have positive self-efficacy. The findings support Schöber et al. (2018) and Aida and Ali (2009) acknowledgment of self-efficacy as both a causative agent and an influence on students’ academic achievement. Liu and Koirala (2009) used regression analysis to evaluate the association between high school students mathematics self-efficacy and mathematics achievement. Liu and Koirala (2009), Trujillo and Tanner (2014), and Appiah et al. (2022) discovered that mathematics self-efficacy was a strongly favorable predictor of mathematics achievement, confirming the study's findings. Zhang et al. (2022), Blackmore et al. (2021), and Flowers and Banda (2016) all support this finding and admonished that one must initially recognize the direct effects of self-efficacy on academic achievement before building a strategy for boosting students' migration from SHS to tertiary education to pursue STEM-related programs.

According to the findings of this study, students' perception of mathematics has no direct effect on mathematics achievement among general science students, nor does student study interest mediate between their constructs. Student achievement drops by 0.073 when perception rises by one. This is not surprising considering that students at the sampled senior high schools are already determined to study general science, which requires additional mathematics as an elective subject supporting Middleton and Spanias (1999) regarding the needed motivation. Perception in mathematics, for that matter, has little or no direct impact on their achievement or even with study interest mediating between perception and achievement. In Ghana, most of our outstanding students are recruited to study general science, and for that matter, there is a constraint to the link between perception and achievement based on their higher cognitive capacities as indicated by Henry (2012) and Vukovic et al. (2013).

Although students may have their own opinions about mathematics difficulties as proposed by (Y. Arthur et al., 2017), which may affect their self-efficacy in mathematics (Oluwafunmilayo, 2013), it does not appear to have an impact on their achievement. As revealed by Siegle et al. (2014) and Winheller et al. (2013), competition in the mathematical classroom, teachers and other students' attitudes towards mathematics edge students to be more optimistic about the subject devoid of any perceived intentions of failure, making the school environment inspirational grounds to minimized perception.

Again, the direct influence of students' mathematical connectedness on mathematical achievement was substantial. General science students are motivated to understand mathematics as a cognitive process and it is relevant to so many facets of daily life when it is connected to actual life situations (García-García & Dolores-Flores, 2018). In doing so, they stimulate their curiosity by connecting mathematical ideas and concepts into science, technology, and engineering by solving and designing algorithms, which significantly improves their achievement, as supported by Sari and Karyati's (2020) findings.

Self-efficacy is argued and proved to be domain-specific, which indicates that having strong self-efficacy in one field does not always translate to achievement in a related subject, and the student must have some interest in the subject (Callaman & Estela, 2020).

The study also revealed that the mathematics connection demonstrates a direct association with student achievement. Notwithstanding this, the study also revealed that student study interest moderates mathematics connectivity and student achievement relationships. This means that no matter how well the educators connect and apply mathematics to STEM in the classroom if the student has no interest in it, he or she will underperform in mathematics activities as posited by Wong and Wong (2019). The competitiveness among students and their desire to partake in STEM-related competitions have compelled the chosen schools to be well equipped with modern technology that makes mathematics instruction more practical, so it was not surprising to discover student interest mediating between mathematical connection and student achievement was considerable, as confirmed by Menanti et al.'s (2018) findings.

8. Limitation and Strength

The term STEM education as a full-fledged division distinct from the Ghana Education Service (GES) under the Ministry of Education is relatively new in Ghana, but it has long been a vital aspect of senior high school science programs. As a result, STEM education is an area that Ghanaian researchers have not yet investigated. Aside from its originality, the study of the mathematics achievement of STEM students in senior high school using a structural equation model based on their self-efficacy, mathematical connection to other subjects and fields, and perception of mathematics as mediated by student study interest is noteworthy. This study produced fresh findings about the causative effects of STEM students' mathematical achievement on self-efficacy, perception, and connection, as well as the mediating strength of their study interest to acquire access to further their STEM ambitions at the higher education level.

Despite the study's positives, there are several limitations. To begin with, there are relatively few STEM schools in the country, and they are up to Level One only, with a smaller student body and still employing the GES general science curriculum. As a result, choosing these STEM institutions was no longer an ideal option for our study, which instead focused on the traditional general science programs that have kept STEM education in Ghana up to date. Finally, there were some challenges in getting all three forms of general science students to fill out the questionnaire, as form three was writing the WASSCE examination, and form two students were on vacation, forcing the researchers to spend two months collecting data.

9. Conclusion and Recommendation

The study concludes general science students' mathematics self-efficacy and connection directly impact their mathematics achievement and, at the same time, partially mediate through their study interest to perform well in mathematics. However, there was no relationship between perception in mathematics and student interest or achievement.

The study recommends that the stakeholders, curriculum developers, and implementers of the new STEM curriculum try as much as possible to connect mathematics in STEM with science, technology, and engineering in practical life situations to either directly improve their achievement or to boost their interest to enhance their achievement in STEM education. Even though perceptions of mathematics do not affect their study interest or achievement due to their growing tenacity to pass mathematics and qualify academically for their respective dream STEM career programs, researchers still advise mathematics teachers to motivate them to spell out all misconceptions about mathematics studies. Furthermore, students must keep on evaluating the efficiency of their learning strategies to achieve academic greatness and must make reliable and self-efficacious evaluations of their mathematical learning to improve their study interest and also enhance their mathematics achievement. Teachers must also critically take into account the pedagogical approach used in teaching the students to connect mathematics with other subjects and also to uplift their students' self-efficacy and interest in achieving something worthwhile in mathematics education.

We recommend that future research focus independently on the situational and individual study interests of the students as mediating factors to achievement while also including STEM students' gender in the path analysis to ascertain the moderating impact on their achievements, as there is a remarkable gap of 15.4% between the genders in this study.

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