Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

The impact of motivation on mathematics achievement of Saudi students using structure equation method and mediation analysis

Ibtesam Ali Alsaggaf*, Nahlah Abdulgabar

Department of Statistics, King Abdulaziz University, Jeddah, Saudi Arabia

ARTICLE INFO

Article history:
Received 9 November 2023
Received in revised form
28 February 2024
Accepted 12 March 2024

Keywords:
Academic motivation
Math achievement
Mediation analysis
School bullying
Self-concept

ABSTRACT

This study focuses on the decline in math scores among fourth-grade students in Saudi Arabia, which is a significant concern. The Saudi Arabian Ministry of Education is taking steps to improve education and provide students with the necessary skills for their future careers. Understanding what affects student achievement is key to solving this problem. Motivation in education is a critical factor that influences students' attitudes and their success in school. This research looks at how academic motivation affects educational success through a process called mediation analysis. It considers how self-concept and values, which come from motivation, play a role. The study uses the expectancy-value theory of achievement motivation to create a model that explores how motivation and other factors like school bullying, feeling connected to school, and perceptions of teachers interact and affect each other. Mediation analysis helps examine the direct and indirect effects these factors have on student achievement. Data from the trends in international mathematics and science study (TIMSS) for fourth graders in Saudi Arabia is used to see if the theory fits with the experiences of Saudi students. The findings show that self-confidence is crucial for academic performance, affecting students' motivation, readiness to face challenges, and overall learning attitude. However, math attitude does not directly influence self-concept. School bullying is identified as a significant negative factor in math achievement. These outcomes stress the need to address school bullying to improve math scores and highlight the importance of self-concept and motivation in boosting academic success.

1. Introduction

One of the goals of the Kingdom of Saudi Arabia (KSA) in Vision 2030 is to develop education, as the Ministry of Education (MOE) is highlighted as the second topic of the KSA 2030 vision (Fakeeh, 2016; Alghamdi et al., 2022). To meet its educational objectives, Saudi Arabia has actively engaged in various international education assessments, including the Trends in International Mathematics and Science Study (TIMSS). This participation helps Saudi Arabia evaluate its students' academic performance against global standards, which is crucial for enhancing the educational system and improving the quality of education for students.

Results from TIMSS revealed that the average performance of Saudi fourth graders was consistently below the international midpoint score of 500, with scores of 410, 383, and 398 in the years 2007, 2011, and 2019, respectively (Alghamdi, 2021). These findings underscore the urgent need for improvements in mathematics education and highlight the importance of equipping students with essential skills and knowledge. Additionally, they point to the necessity of exploring various factors that influence student achievement in mathematics.

The TIMSS questionnaires are structured to assess a broad range of factors that might impact student learning. These include the school setting, administrative support, teaching quality, home environment, and motivational and psychological factors that could influence a student's learning capabilities (Michaelides et al., 2019).

Student motivation is an important factor in academic achievement. There are several different constructs involved in motivation, including ability self-concepts, task values, goals, and achievement motives. Other factors, such as teacher, home, and

* Corresponding Author.
Email Address: ialsaggaf@kau.edu.sa (I. A. Alsaggaf)
https://doi.org/10.21833/ijaas.2024.03.024
Corresponding author's ORCID profile:
https://orcid.org/0009-0004-6356-7095

school environment, could also affect student achievement. Therefore, it is important to consider diverse motivational constructs to predict school students' achievement (Steinmayr et al., 2019). It is important to consider these factors when trying to improve student motivation and achievement in education.

Mediation analysis using the structural equation model (SEM) is a powerful technique that helps to investigate the relationship between the different factors and student achievement through the motivation construct.

Motivational constructs have been assessed in TIMSS achievement studies in Math and Science since 1995 (Mullis and Martin, 2017). Constructs such as confidence, enjoyment, and value of Math and Science have been measured using several items included in the student background questionnaires (Michaelides et al., 2019).

Numerous studies have been conducted on the impact of various motivational factors and other variables on student math achievement. These studies aim to identify the factors that play a significant role in the academic success of students. Some of the factors that have been studied include parental involvement, teacher support, student motivation, and self-efficacy.

Abu-Hilal et al. (2013) conducted a study using a TIMSS 2007 for Saudi 8th-grade students. They divided student self-concept into two parts: Cognitive, which refers to an external reference, and affective, which refers to an internal reference. Based on SEM analysis, it appears that separating self-concept into cognitive and affective components made the structure clearer than combining them. The study also found that the relationships among cognitive, affective, and subject value in Math and science were consistent across genders but not with achievement across genders.

In Tighezza's (2014) study, eighth-grade data was used to examine the validity of two models of science achievement, namely full mediation and partial mediation. The study used three variables, active learning, school connectedness, and science attitude, through two mediating variables: science value and self-confidence. The three variables were then linked through two mediating variables, namely science value and self-confidence. The study employed structural equation modeling to examine the hypothesized relationship among the variables. The results showed that the indirect relationship through self-confidence was supported, except for school connectedness, while all direct and indirect effects of science values were statistically nonsignificant. Additionally, both hypothesized models were shown to fit the data adequately. Finally, the chi-square difference test showed that the partial-mediated model produced results that were closer to the sample covariance matrix compared to the full-mediation model.

Alotaibi (2019) examined the impacts of attitudes, normative beliefs, subjective norms, and perceived behavioral control/self-efficacy on intentions of cyberbullying and expected societal outcomes. The data was collected by questionnaire from high school students from the 9th to 12th grades in Saudi schools. Multiple linear regression was conducted to analyze the data. They found that several factors can contribute to cyberbullying intentions, such as social media use and the absence of parental controls. Furthermore, the intentions towards cyberbullying can have a direct negative impact on a student's academic performance.

Alshaikh (2021) delved into the causes behind the subpar science performance of eighth-grade students from Saudi Arabia in TIMSS. The study employed a descriptive methodology and formulated a questionnaire comprising three dimensions: course content, student, and teacher and teaching performance. According to the findings, there was a widespread consensus among the study participants regarding all the items in the questionnaire.

Elsayed et al. (2022) studied the differences in academic performance between fourth and eighth-grade boys and girls in mathematics and science. A hierarchical two-level linear regression technique was adopted to investigate the impact of some factors. Based on TIMSS 2019 and national Saudi Arabia assessment data, the study highlights the importance of school climate in determining boys' academic success. Boys attending schools with poor climates performed significantly worse than girls in similar schools. Additionally, the study found that student absenteeism had a particularly negative impact on boys' mathematics achievement.

This research aims to use mediation analysis to develop a model that demonstrates the influence of motivational factors, including self-concept and Math attitude, as well as other predictor factors like school bullying, teacher concept, and school connectedness on math achievement for grade 4 students. The research is based on data gathered from the TIMSS 2019 Saudi Arabia database.

2. Student motivation and expectancy-value theory

Motivation research is fundamental to the science of human behavior generally, and it is also related to educational science (Ryan, 1998). Motivation refers to the reasons, purposes, values, intentions, feelings, goals, attitudes, intuitions, and beliefs that people use to clarify why they do what they do (Mercier and Sperber, 2017).

The investigation of student motivation is important in educational settings because it reacts to educational decisions and achievement behavior in significant ways (Deci and Ryan, 2013; Eccles and Wigfield, 2002; Hattie, 2008). Several studies have found that motivational factors are linked to achievement and are also reflected as important predictors of achievement (Hattie, 2008; Lee and Shute, 2010).

The Expectancy-Value Theory (EVT) is a key framework for understanding motivation in educational achievement. EVT consists of two

primary elements: the expectancy component, which involves a student's beliefs about their own ability to complete a task, and the value component, which relates to the student's reasons for engaging in the task and its significance to them (Michaelides et al., 2019). Both these components—expectancy beliefs and task values—are crucial for predicting a student's achievement-related behavior (Wigfield and Eccles, 1992).

All described variants of the EVT are consistent with TIMSS questionnaire items and are related to the context of motivation measures that are used in TIMSS (Michaelides et al., 2019).

3. Method

3.1. Conceptual framework

The EVT is utilized as the theoretical basis in this study to effectively frame our understanding of achievement motivation (Eccles and Wigfield, 2002). This theory aligns well with the motivational content in the TIMSS student background questionnaire and has been thoroughly validated in previous research (Michaelides et al., 2019).

In this research, two motivational constructs are examined within the EVT framework. The expectancy component is represented by academic self-concept, and intrinsic value is captured through the Math attitude construct. The model being analyzed includes Math achievement as the dependent variable and three independent variables: School bullying, school connectedness, and teacher concept. Both self-concept and Math attitude serve as mediators and are considered both independent and dependent variables in the study's structural model (Fig. 1).

From Fig. 1, the relationship between these three predictor variables and the outcome (Math achievement) is explained in two ways: The direct way (in red arrow) and the indirect way (in black arrow). The indirect way is mediated through two motivational variables, represented by Math self-concept and Math attitude. All these effects (direct, indirect, and total) are calculated, as well as the significance of each path through SEM analyses.

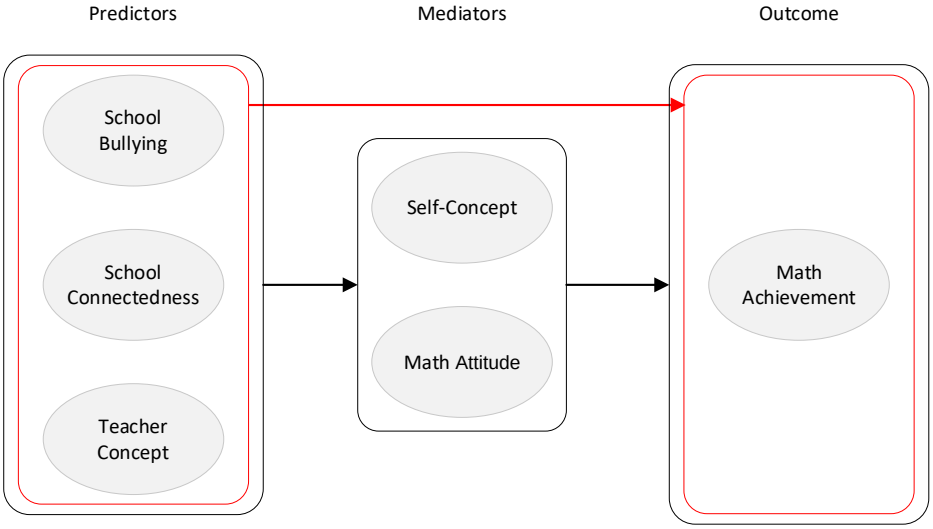

Fig. 1: General framework of the predictors of math achievement through mediator variables

3.2. Data and variables

The data were obtained from TIMSS 2019 Saudi Arabia. The sample consisted of 5453 grade 4 students with an average age of 9.5 years (Martin et al., 2020). The variables of interest for this study were selected from the student background questionnaire. All selected questions are on a four-point Likert scale, from disagree a lot (4) to agree a lot (1). For the present analysis, all selected items were reverse-coded except negative statements. The selected questions represent five constructs: Self-concept, Math attitude, school bullying, school connectedness, and teacher concept. Table 1 shows the statements (items) that form each construct.

For some latent variables (factors), TIMSS created the Rasch Scale as an “Average Scale Score” with an index that reported the percentages of students in each category ”Agree,” ” Somewhat Agree,” and “Do Not Agree” (Martin et al., 2020). Therefore, the two mediator variables were selected from the database as an observed scale variable to get a simpler model.

For some latent variables (factors), TIMSS created the Rasch Scale as an “Average Scale Score” with an index that reported the percentages of students in each category ”Agree,” “Somewhat Agree,” and “Do Not Agree” (Martin et al., 2020). Therefore, the two mediator variables were selected from the database as an observed scale variable to get a simpler model.

Math achievement scores were derived from the TIMSS achievement test. TIMSS designed 14 assessment blocks containing math items, which were distributed across 14 booklets to create a uniform set of assessments. Each student in the participating classroom received only one math booklet, meaning that each group of students completed only one block of the assessment (Mullis and Martin, 2017). This method results in a limited set of math items per student, leading to a significant amount of missing data. This assessment approach is

known as multi-matrix sampling or balanced incomplete block designs.

To analyze the data from these assessments, Item Response Theory (IRT) is employed to amalgamate results across all booklets, providing comprehensive assessment outcomes. For a robust estimation of student achievement, TIMSS uses multiple imputations, specifically generating what are termed Plausible Values (PV). These PVs are calculated by creating five random values from each student's ability distribution to accurately represent their math achievement scores (Von Davier, 2019). This method enhances both the precision of the achievement estimates and the estimation of error. These plausible values are crucial in forming the achievement construct used in the analysis.

Table 1: Latent variables and corresponding questionnaire items

Self-concept	Math attitude
"I usually do well in math"	"I like any schoolwork that involves numbers"
"Math is more difficult for me than of my classmates"	"I wish I did not have to study math"
"I am not good at math"	"Math is boring"
"I learn thigs quickly in math"	"I learn many interesting things in math"
"Math makes me nervous"	"I like math"
"I am good at working out difficult math problems"	"I enjoy learning math"
"My teacher tells me I am good at math"	"I like to solve math problems"
"Math is harder for me than any other subject"	"I look forward to math class"
"Math makes me confused"	"Math is one of my favorite subjects"
School bullying	**School connectedness**
"I was made fun of or called names"	"I like being in school"
"Excluded me of games or activities by others"	"I feel safe when I am at school"
"Someone spread lies about me"	"I feel like I belong at this school"
"Made me do things I didn't want to do"	"Teachers at my school are fair to me"
"Something was stolen from me"	"I am proud to go to this school"
"I was hit or hurt by others"	**Teacher concept**
"Posted embarrassing things about me online"	"I know what my teacher expects me to do"
"Threatened me"	"My teacher is easy to understand"
"Sent me nasty or hurtful messages online"	"My teacher has clear answers to my questions"
"Shared nasty or hurtful things about me online"	"My teacher is good at explaining math"
"Damaged something of mine on purpose"	"My teacher does a variety of things to help us learn"
	"My teacher explains a topic again when we don't understand"

3.3. Descriptive statistic

Tables 2 and 3 give descriptive statistics according to the predictors and mediators factors corresponding to student achievement.

Table 2 describes the mean of the math achievement depending on each category of the mediators, while Table 3 describes the mean of the achievement depending on each category of the factors: school connectedness, school bullying, and teacher concept. From Table 2, it appears that the mean of achievement increases when the confidence of the student increases. The achievement also increases when the student likes the subject more.

From Table 3, students who have higher school connectedness perform better in mathematics. Likewise, concerning the teacher concept, students who have a higher teacher concept present higher achievement. As for bullying, it has the opposite effect. Students who are exposed to bullying more have a lower academic performance.

Table 2: Mean achievement of math corresponding to the predictors' factors

Categories	Factors					
	School connectedness		School bullying		Teacher concept	
	N	Mean	N	Mean	N	Mean
Very low	114 (2.2%)	388.48	3159 (61%)	425.07	81 (1.6%)	364.06
Low	311 (% 6)	390.57	1131 (21.8%)	402.07	140 (2.7%)	358.55
Medium	899 (17.4%)	390.32	613 (11.8%)	362.78	762 (14.9%)	374.03
High	3847 (74.4%)	414.44	278 (5.4%)	342.86	4115 (80.7%)	417.88

Table 3: Mean achievement of math corresponding to the mediators' factors

Students confident in mathematics			Students like learning mathematics		
	N	Mean		N	Mean
Not confident	821 (16.3%)	352.44	Do not like	567 (11.1%)	377.26
Somewhat confident	1984 (39.4%)	393.46	Somewhat like	1526 (29.8%)	381.46
Very confident	2229 (44.3%)	444.27	Very much like	3027 (59.1%)	428.43

3.4. Exploratory factor analysis

Exploratory Factor Analysis (EFA) is used here not as part of the SEM process but to explore data and confirm the structure of the constructs. EFA was applied to four latent constructs: Student Achievement, School Bullying, Teacher Concept, and School Connectedness using the maximum likelihood

estimation method and Promax rotation. The Kaiser-Meyer-Olkin (KMO) measure for sampling adequacy returned a value of 0.933, indicating an excellent level. According to the results, each item loaded significantly onto its intended factor, with no cross-loadings exceeding 0.3, which suggests a clear factor structure.

However, some items showed low factor loadings; specifically, the item "Fair teachers" under the School Connectedness construct loaded at 0.432, and the item "Teacher expects what to do" under the Teacher Concept construct loaded at 0.342. These loadings suggest that these items may be candidates for removal in the CFA model to enhance model fit and clarity. Additionally, the analysis indicated that the School Bullying construct could be subdivided into two distinct domains—cyberbullying and student bullying—suggesting the need for these to be treated as separate constructs in subsequent analyses. Table 4 clearly illustrates these findings, showing the items' respective loadings and the suggested splits in constructs.

Table 4: EFA pattern matrix

Question	Factor				
	1	2	3	4	5
Being in school (SC1)				0.605	
Safe at school (SC2)				0.588	
Belong at school (SC3)				0.715	
Teachers fair (SC4)				**0.432**	
Proud to go to this school (SC5)				0.661	
How often/made fun of (SB1)		0.687			
How often/left out of games (SB2)		0.524			
How often/spreading lies about me (SB3)		0.697			
How often/stealing things from me (SB4)		0.642			
How often/damaging things of mine (SB5)		0.696			
How often/hurt by others (SB6)		0.751			
How often/force to do things (SB7)		0.455			
How often/sent hurtful messages (SB8)					0.69
How often/shared things online (SB9)					0.834
How often/shared photos online (SB10)					0.743
How often/threatened (SB11)		0.522			
Teacher expects what to do (TC1)			**0.342**		
Teacher is easy to understand (TC2)			0.554		
Clear answers (TC3)			0.72		
Teacher explains good (TC4)			0.726		
Teacher does a variety (TC5)			0.671		
Teacher explains again (TC6)			0.506		
1st plausible value mathematics (PV1)	0.944				
2nd plausible value mathematics (PV2)	0.937				
3rd plausible value mathematics (PV3)	0.947				
4th plausible value mathematics (PV4)	0.937				
5th plausible value mathematics (PV5)	0.943				

Bold: Loading < 0.5

3.5. Measurement model

CFA is applied to the latent variables: school bullying, teacher concept, school connectedness, and Math achievement. Since the school bullying construct is divided into two main sub-constructs, Cyberbullying, and student bullying, as EFA suggested, a second-order CFA model is proposed for school bullying constructs. The higher-order technique is used to confirm that the second-order construct (school bullying) loads into the respective first-order constructs (sub-constructs) (cyberbullying, student bullying). Fig. 2 shows the CFA of the measurement model.

Table 5 shows correlation estimates between the higher order of school bullying, and the other three latent variables, with the bootstrap confidence intervals and corresponding p-value. The highest correlation is 0.518 which indicates that no collinearity between the latent factors. The correlation between Math achievement and the two latent, school connectedness and teacher concept is positive and weak. It is 0.101 and 0.247, respectively**,** while the correlation between school connectedness and teacher concept is moderate and positive =0.518. The correlation between the higher order of school bullying and the three latent, Math achievement, school connectedness, and teacher concept is negative and weak. Note that all correlations are significant at p-value=0.001. As shown in Table 6, the model fit indices values reached an excellent level in the measurement model, except χ^2 /df is slightly greater than 5. CFI, TLI, NFI, AGFI, and GFI exceed the cut-off point of 0.95, suggesting an excellent model fit, as well as RMSEA that is reaching a very good value (0.03<0.05), and no fit modification is needed.

Table 5: Correlation estimates in the CFA

Parameter			Estimate	Lower	Upper	P-value
Achievement	<->	Teacher concept	0.247	0.218	0.277	0.001*
Achievement	<->	School connectedness	0.101	0.068	0.134	0.001*
Achievement	<->	Higher order SB	-0.346	-0.374	-0.32	0.001*
Teacher concept	<->	School connectedness	0.518	0.481	0.556	0.001*
School connectedness	<->	Higher order SB	-0.276	-0.32	-0.236	0.001*
Teacher concept	<->	Higher order SB	-0.313	-0.351	-0.273	0.001*

*: P-value<0.05

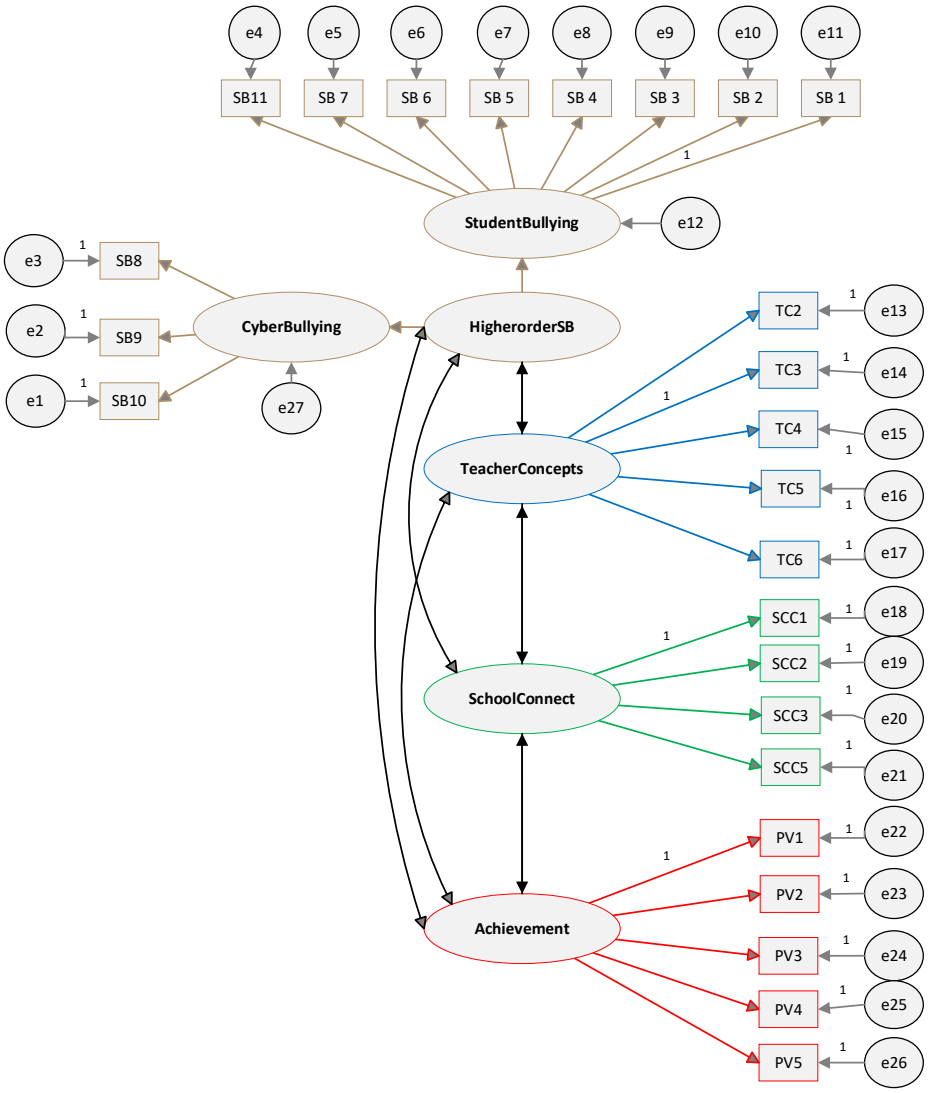

Fig. 2: CFA of the measurement model

Table 7 shows the standardized estimates and the bootstrap confidence interval for observed variables in the model, as well as the p-value. As shown in Table 7, all factor loadings on the latent variables in the CFA model are significant (p-value<0.01) and sufficiently high (>0.5). Note that the variables TC1 and SCC4 are deleted from the model as suggested by EFA.

The three-item loadings under the cyberbullying construct are sufficiently high (>0.7), and the two sub-constructs (cyberbullying, student bullying) load high under the higher-order school bullying construct, which equals 0.951 and 0.819, respectively, confirming that the theorized second-order construct loads into the respective first-order constructs (sub-constructs) very well (Table 7).

The validity and reliability of the measurement model are assessed. A construct is considered reliable if the Composite Reliability (CR) is 0.6 or higher. Convergent validity is achieved when all factor loadings are statistically significant and exceed 0.5 and when the Average Variance Extracted (AVE) is 0.5 or greater (Civelek, 2018; Said et al., 2011; Ahmad et al., 2016). However, if the AVE is 0.4 but the CR is above 0.6, the convergent validity is still considered adequate (Fornell and Larcker, 1981).

Discriminant validity is evaluated by ensuring that the square root of the AVE (SAVE) for each construct is greater than the correlations between constructs. According to Table 8 in the study, all constructs meet the required thresholds for construct reliability (CR ≥ 0.60). Although the AVE for the School Connectedness and Teacher Concept constructs are below the ideal threshold (0.425 and 0.452, respectively), their CR values (0.747 and 0.803, respectively) and the fact that AVE values are above 0.4 confirm that their convergent validity is still acceptable. Furthermore, the condition for discriminant validity is met as the SAVE values are larger than the inter-construct correlations, ensuring adequate discriminant validity.

Table 6: Model fit indices for the CFA

Model fit index	χ^2 /df	NFI	TLI	CFI	AGFI	GFI	RMSEA
Model fit value	5.582	0.98	0.982	0.984	0.971	0.976	0.03
Acceptable threshold	≤5	≥.90	≥.90	≥.90	≥.90	≥.90	≤ 0.08

Table 7: Summary of items loadings for model

Variable name	AMOS code	Estimate	Lower	Upper	P-value
School connectedness	SCC1	0.608	0.574	0.639	0.001*
	SCC2	0.619	0.586	0.648	0.001*
	SCC3	0.686	0.655	0.715	0.001*
	SCC5	0.691	0.661	0.719	0.001*
Higher-order school bullying	Student bullying	.819	.783	.849	.002*
	Cyberbullying	.951	.919	.988	.001*
Student bullying	SB1	0.622	0.601	0.643	0.001*
	SB2	0.581	0.557	0.602	0.001*
	SB3	0.651	0.631	0.672	0.001*
	SB4	0.637	0.615	0.659	0.001*
	SB5	0.715	0.697	0.734	0.001*
	SB6	0.688	0.668	0.706	0.001*
	SB7	0.69	0.669	0.71	0.001*
	SB11	0.679	0.658	0.699	0.001*
Cyberbullying	SB8	0.785	0.762	0.806	0.001*
	SB9	0.835	0.816	0.853	0.001*
	SB10	0.797	0.775	0.819	0.001*
Teacher concept	TC2	0.605	0.568	0.635	0.001*
	TC3	0.723	0.691	0.752	0.001*
	TC4	0.765	0.74	0.792	0.001*
	TC5	0.694	0.661	0.725	0.001*
	TC6	0.552	0.516	0.586	0.001*
Achievement	PV1	0.94	0.936	0.943	0.001*
	PV2	0.941	0.938	0.945	0.001*
	PV3	0.945	0.941	0.948	0.001*
	PV4	0.942	0.938	0.945	0.001*
	PV5	0.942	0.938	0.945	0.001*

*: P-value<0.05

Table 8: Summary of validity and reliability for the CFA model

	CR[1]	AVE[2]	School connectedness	Achievement	Teacher concept	Higher order SB
School connectedness	0.747	0.425	**0.652**			
Achievement	0.975	0.887	0.101	**0.942**		
Teacher concept	0.803	0.452	0.518	0.247	**0.672**	
Higher order SB	0.881	0.788	0.276	0.346	0.313	**0.887**

1: Construct Reliability; 2: Average Variance Extracted; SB: school bullying; Shaded cell: Inter-construct correlation; Bold: The SAVE value

To check if there is a common variance between latent variables, the Common Latent Factor (CLF) is added to the CFA model (Fig. 3). Table 9 shows the standardized regression weights after adding CLF to the model, the standardized regression weights of a model without CLF, and the difference between those two estimates. From Table 9, there are no large differences greater than |0.2|. That means there is no common variance among the observed variables in the model.

Table 9: Standardized regression weights with and without CLF for model

Standardized regression weight			With CLF	Without CLF	Deference
ASMMAT01	<--	Achievement	0.857	0.94	-0.083
ASMMAT02	<--	Achievement	0.851	0.941	-0.09
ASMMAT03	<--	Achievement	0.859	0.945	-0.086
ASMMAT04	<--	Achievement	0.841	0.942	-0.101
ASMMAT05	<--	Achievement	0.85	0.942	-0.092
Cyberbullying	<--	Higher order SB	0.824	0.951	-0.127
Student bullying	<--	Higher order SB	0.91	0.819	0.091
SB8	<--	Cyberbullying	0.784	0.785	-0.001
SB9	<--	Cyberbullying	0.835	0.835	0
SB10	<--	Cyberbullying	0.798	0.797	0.001
SB1	<--	Student bullying	0.624	0.622	0.002
SB2	<--	Student bullying	0.579	0.581	-0.002
SB3	<--	Student bullying	0.652	0.651	0.001
SB4	<--	Student bullying	0.637	0.637	0
SB5	<--	Student bullying	0.715	0.715	0
SB6	<--	Student bullying	0.689	0.688	0.001
SB7	<--	Student bullying	0.688	0.69	-0.002
SB11	<--	Student bullying	0.679	0.679	0
SCC1	<--	School connectedness	0.614	0.608	0.006
SCC2	<--	School connectedness	0.616	0.619	-0.003
SCC3	<--	School connectedness	0.684	0.686	-0.002
SCC5	<--	School connectedness	0.69	0.691	-0.001
TC2	<--	Teacher concept	0.626	0.605	0.021
TC3	<--	Teacher concept	0.728	0.723	0.005
TC4	<--	Teacher concept	0.748	0.765	-0.017
TC5	<--	Teacher concept	0.677	0.694	-0.017
TC6	<--	Teacher concept	0.525	0.552	-0.027

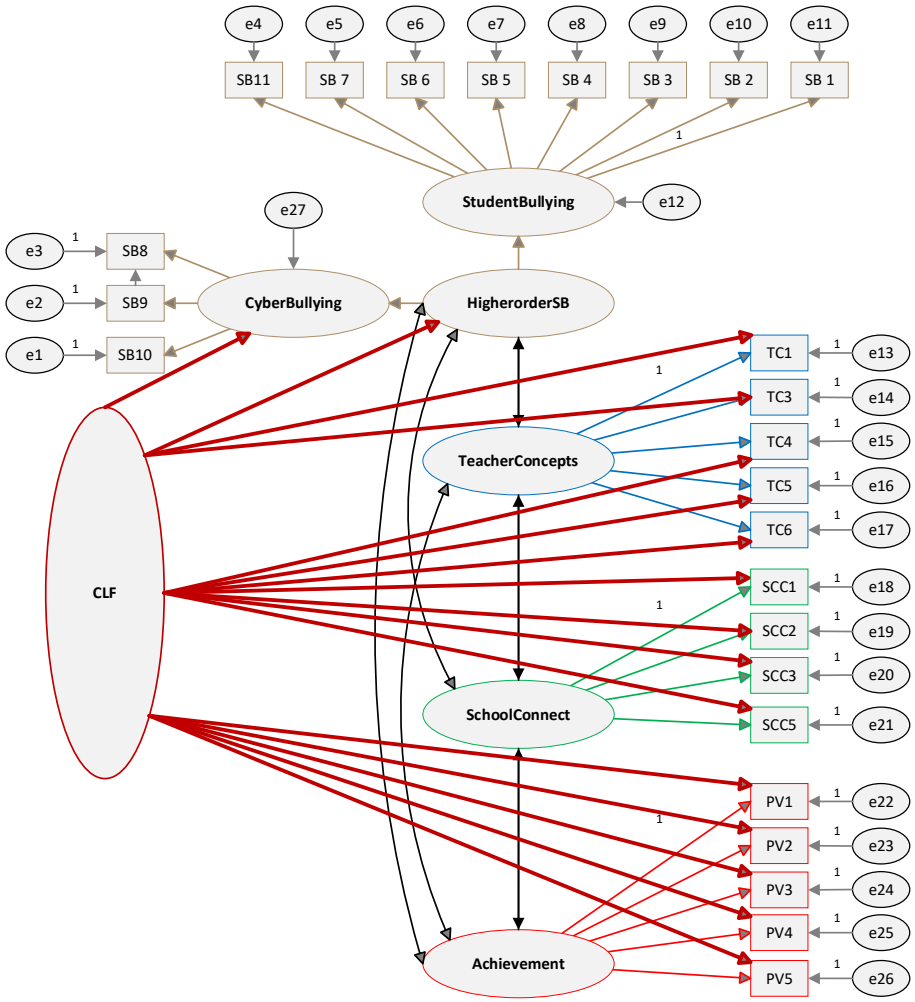

Fig. 3: Common latent factor in the CFA model

3.6. Structure equation model

Fig. 4 shows the Structure equation model for grade 4. SEM requires that there is no multicollinearity between the variables. Multicollinearity appears if two or more variables are so highly correlated, which indicates that they both represent the same construct (Byrne, 2011). Multicollinearity is assessed using the measurements tolerance and VIF. Table 10 shows the values of the multicollinearity statistics for each factor and the cut-off points. All results show no multicollinearity between the variables in the structural model since all values of tolerance are greater than 0.2, and the VIF values are below the cut-off point of 5.Table 11 presents the fit indices of the structural model in Fig. 4. All indices' values of the SEM model, NFI, TLI, CFI, AGFI, and GFI refer to a good model where their values are greater than 0.95, and RMSEA value <0.05. The $\chi 2$ /df statistic equals 7.38, which is not too far from the cut-off point 5. This inflation is due to its sensitivity to large sample sizes (West et al., 2012). Modification Indices (MI) are calculated in most SEM software and can be used to adjust the model fit (Civelek, 2018; Hox and Bechger, 1998; Khine, 2013). From MI values, the MI regression weight is high and equal to 383.006, suggesting a path from self-concept to math attitude. After adding this path to the model, the model fit improved (Table 12). In addition, adding this path indicates adding serial mediation to the SEM model. Fig. 4 shows the SEM model after adding the new causal path from self-concept to Math attitude.

Table 10: Tolerance, variance inflation factor for multicollinearity test

Factor	Collinearity statistics	
	Tolerance	VIF
School bullying	.787	1.271
School connectedness	.528	1.893
Teacher concept	.475	2.105
Math attitude	.508	1.969
Self- concept	.638	1.568
Cut-off point	> 0.2	< 5

Dependent variable: Achievement

Table 11: Model fit indices for SEM model

Model fit index	χ^2 /df	NFI	TLI	CFI	AGFI	GFI	RMSEA
Model fit value	7.38	0.97	0.97	0.98	0.96	0.97	0.035

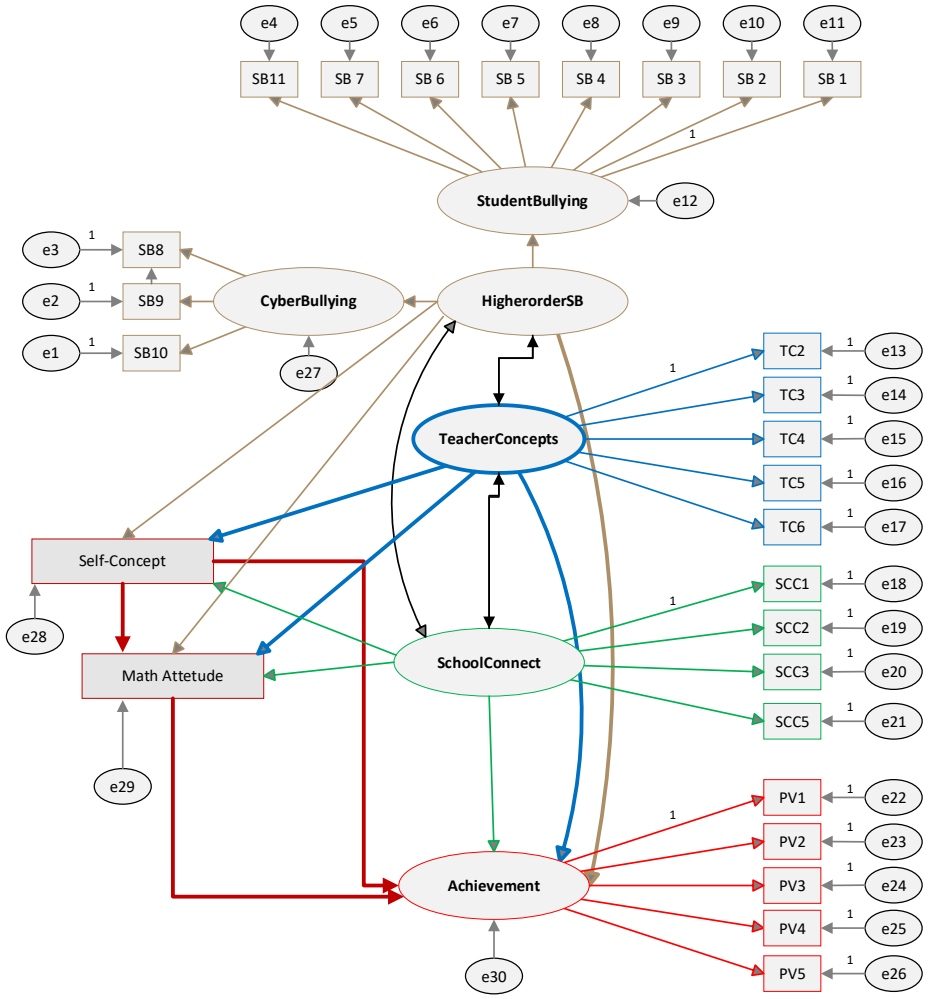

Fig. 4: The SEM model, TIMSS grade 4

Table 12: Final model fit indices for SEM model after modification, grade 4

Model fit index	χ^2 /df	NFI	TLI	CFI	AGFI	GFI	RMSEA
Model fit value	5.44	0.979	0.981	0.983	0.97	0.98	0.035

3.7. Mediation analyses

This section illustrates the calculation and analysis of the considered constructs' effects on the dependent variable (achievement) as well as the direct, indirect, and total effects. Two types of specific indirect effects are illustrated and calculated: Serial and parallel mediation effects. Fig. 4 shows the SEM model with all the relationships between the constructs, the two mediators, and the dependent variable. To simplify the whole picture of the calculations, the effects of each factor (direct, parallel, and serial-specific indirect) will be explained separately.

3.7.1. Mediators' path

From Fig. 5, two paths describe the direct effect of the two mediators to Math achievement: Self-concept (M1) and Math attitude (M2). Another pathway (M3) is added to test the causal relationship between the mediators from self-concept to Math attitude, which represents the serial mediator. Table 13 shows the path names, standardized direct effects from each mediator to achievement, within mediators, and p-values.

The results indicate that paths M1 and M3 have a significant impact with a p-value less than 0.01. Specifically, self-concept positively influences achievement with a magnitude of 0.261 for M1. Additionally, the pathway showing the mediating effect of self-concept on math attitude is also positive, with a magnitude of 0.321 for M3. However, path M2 is not significant, suggesting that math attitude does not significantly affect achievement when self-concept is considered, as supported by Boe et al. (1999). Furthermore, any indirect effects from the predictors through math attitude to achievement are expected to be non-significant.

Table 13: Relationship between mediators and achievement

Direct effect			Path	Effect	P-value
Self-concept	→	Achievement	M1	0.261	0.001*
Math attitude	→	Achievement	M2	0.01	0.601
Self-concept	→	Math Attitude	M3	0.321	0.001*

*: P-value<.05

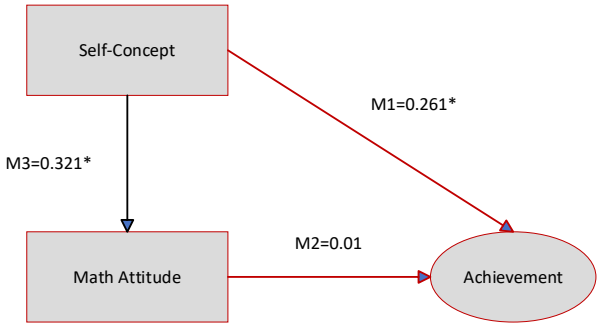

Fig. 5: Relationship between mediators and achievement; *: P-value<0.05

Teacher concept

The teacher concept construct is attached to the two mediators by the a1 and a2 paths, while d1 represents the direct effect of teacher concept on achievement (Fig. 6). Two specific parallel indirect effects are calculated. The first one is from teacher concept to Math achievement through self-concept mediator (a1M1), and the other one is from teacher concept to Math achievement through Math attitude mediator (a2M2).

Results in Table 14 show the direct and significant effect of teacher concept on Math attitude, self-concept, and achievement, which equals a2=0.303, a1=0.268, and d1=0.122, respectively. These results emphasize how the importance of the teacher affects the student's interest in math topics in the first place and student confidence in math in the second place, which is more than a direct effect of teacher concept on achievement.

The teacher concept has a significant indirect effect through the self-concept mediator (a1M1=0.0699), but a non-significant indirect effect through the Math attitude mediator (a2M2=0.003, p-value=0.592). The specific indirect effect of the serial mediation path is small and non-significant (a1M3M2=0.0008, p-value=0.589). In total, the effect of the teacher concept construct is positive and significant through all the direct and indirect effects and equals 0.1957 at p-value=0.001.

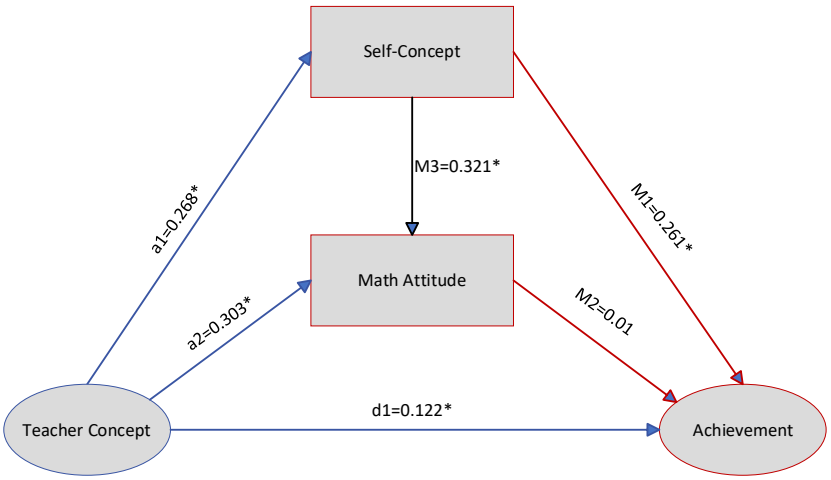

Fig. 6: Teacher concept direct and indirect effects on achievement; *: P-value<0.05

Table 14: Direct, indirect, and total effects of teacher concept

Direct effects					Path	Effect	P-value
Teacher concept	→	Self-concept			a1	0.268	0.001*
Teacher concept	→	Math attitude			a2	0.303	0.001*
Teacher concept	→	Achievement			d1	0.122	0.001*
Specific indirect effect (parallel mediation)					Path	Effect	P-value
Teacher concept	→	Self-concept	→	Achievement	a1M1	0.0699	0.001*
Teacher concept	→	Math attitude	→	Achievement	a2M2	0.003	0.592
Specific indirect effect (serial mediation)					Path	Effect	P-Value
Teacher concept	→	Self-concept → Math attitude	→	Achievement	a1M3M2	0.0008	0.589
Total of teacher concept effects					Path	Effect	P-value
Parallel mediation effect+ Serial mediation effect+ Direct effect					a1M1+ a2M2+ a1M3M2+ d1	0.1957	0.001*

*: P-value<.05

School bullying

The school bullying construct is attached to the two mediators by the b1 and b2 paths, while d2 represents the direct effect of school bullying on achievement (Fig. 7). Two specific parallel indirect effects are calculated; the first one is from school bullying to Math achievement through self-concept mediator (b1M1), and the other one is from school bullying to Math achievement through Math attitude mediator (b2M2).

Results in Table 15 show a negative direct and significant effect of school bullying on self-concept, achievement, and Math attitude, which equals b1=-0.295, d2=-0.231, and b2=-0.034, respectively. This negative relationship suggests that the more bullying takes place on the student, the less the positive self-concept in Math and attitude toward Math learning, and the lower the student's Math achievement scores. Note that the direct effect of school bullying is more on the student confidence in Math and Math achievement than its direct effect on liking the Math subject. School bullying has a significant indirect effect through the self-concept mediator (b1M1=-0.077) but an insignificant indirect effect through the Math attitude mediator (b2M2=-0.00034). The specific indirect effect of the serial mediation path is small and non-significant (b1M3M2=-0.001, p-value=0.587). In total, the effect of the school bullying construct is negative and significant through all the direct and indirect effects=-0.30934.

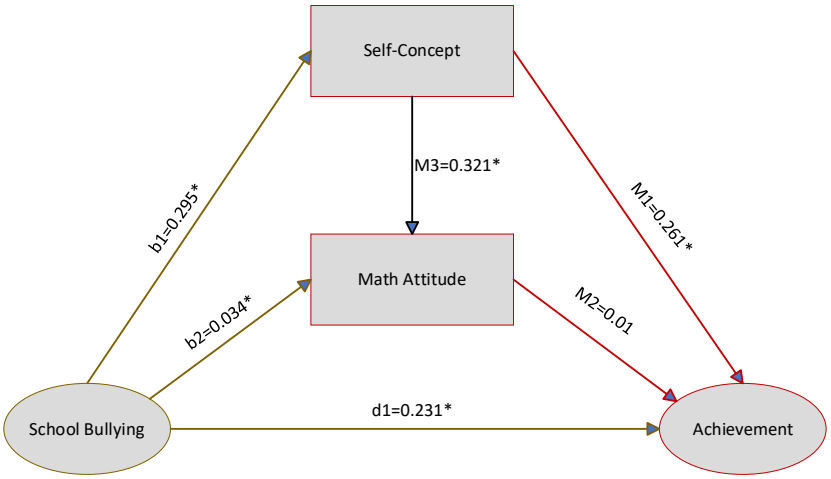

Fig. 7: School bullying direct and indirect effects on achievement, grade4; *: P-value<.05

Table 15: Direct, indirect, and total effects of school bullying, grade4

Direct effects					Path	Effect	P-value
School bullying	→	Self-concept			b1	-0.295	0.001*
School bullying	→	Math attitude			b2	-0.034	0.015*
School bullying	→	Achievement			d2	-0.231	0.001*
Specific indirect effect (parallel mediation)					Path	Effect	P-value
School bullying	→	Self-concept	→	Achievement	b1M1	-0.077	0.001*
School bullying	→	Math attitude	→	Achievement	b2M2	-0.00034	0.421
Specific indirect effect (serial mediation)					Path	Effect	P-value
School bullying	→	Self-concept → Math attitude	→	Achievement	b1M3M2	-0.001	0.587
Total of school bullying effects					Path	Effect	P-value
Parallel mediation effect+ Serial mediation effect+ Direct effect					b1M1+ b2M2+ b1M3M2+ d2	-0.30934	0.001*

*: P-value < .05

School connectedness

The school connectedness construct is attached to the two mediators by the c1 and c2 Paths, while d3 represents the direct effect of school connectedness on achievement (Fig. 8).

Two specific parallel indirect effects are calculated: the first one is from school connectedness to Math achievement through self-concept mediator (c1M1), and the other one is from school connectedness to Math achievement through Math attitude mediator (c2M2). Table 16 shows that all direct paths from school connectedness to mediators are positive and significant, and the highest effect is on Math attitude (c2=0.224) and then self-concept (c1=0.104). The direct effect on Math achievement was significant (d3=-0.12) but negative.

Although the direct effect of school connectedness is the highest on Math attitude, the indirect effect through Math attitude to achievement is small and insignificant (c2M2=0.0022, p-value=0.596), while the other indirect effect through self-concept to achievement is positive and significant (c1M1=0.0271, p-value=0.001). The specific indirect effect of the serial mediation path is very small and non-significant (c1M3M2=0.0003, p-value=0.586). In total, the effect of the school connectedness construct is significant through all the direct and indirect effects and equal -0.0904.

Another suggested serial path

Since the direct effect of the Math attitude on achievement is insignificant (Table 13), The effects of all parallel and serial mediation paths through the Math attitude mediator are not significant for every predictor, as shown in Tables 14, 15, and 16. To test another serial mediation path, the direction of the causal effect will be reversed from Math attitude to the self-concept, as shown in Fig. 9. The direct effect of each predictor on Math attitude (a2, b2, c2) will be multiplied by the path (M4M1) respectively (path in red). Note that the causal path from Math attitude to self-concept M4=0.385 with p-value<0.01.

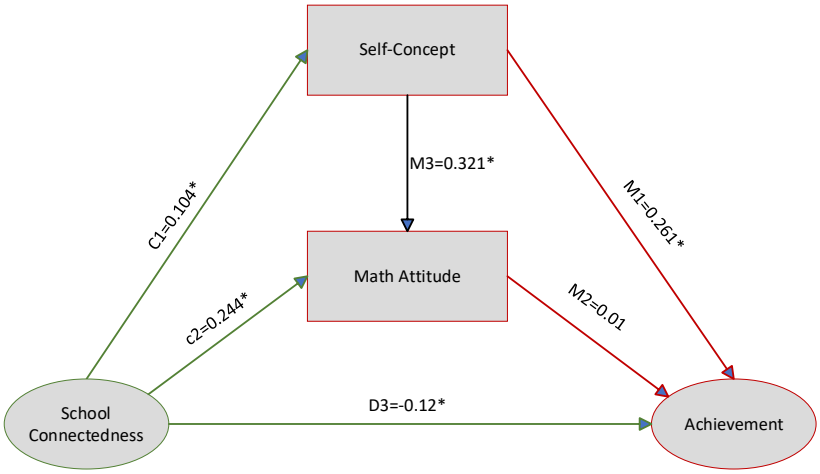

Fig. 8: School connectedness direct and indirect effects on achievement; *: P-value<0.05

Table 16: Direct, indirect, and total effects of school connectedness

Direct effects					Path	Effect	P-value
School connectedness	→	Self-concept			c1	0.104	0.001*
School connectedness	→	Math attitude			c2	0.224	0.001*
School connectedness	→	Achievement			d3	-0.12	0.001*
Specific indirect effect (parallel mediation)					Path	Effect	P-value
School connectedness	→	Self-concept	→	Achievement	c1M1	0.0271	0.001*
School connectedness	→	Math attitude	→	Achievement	c2M2	0.0022	0.596
Specific indirect effect (serial mediation)					Path	Effect	P-value
School connectedness	→	Self-concept → Math attitude	→	Achievement	c1M3M2	0.0003	0.586
Total of school connectedness effects					Path	Effect	P-value
Parallel mediation effect+ Serial mediation effect+ Direct effect					c1M1+ c2M2+ c1M3M2+ d3	-0.0904	0.001*

*: P-value<0.05

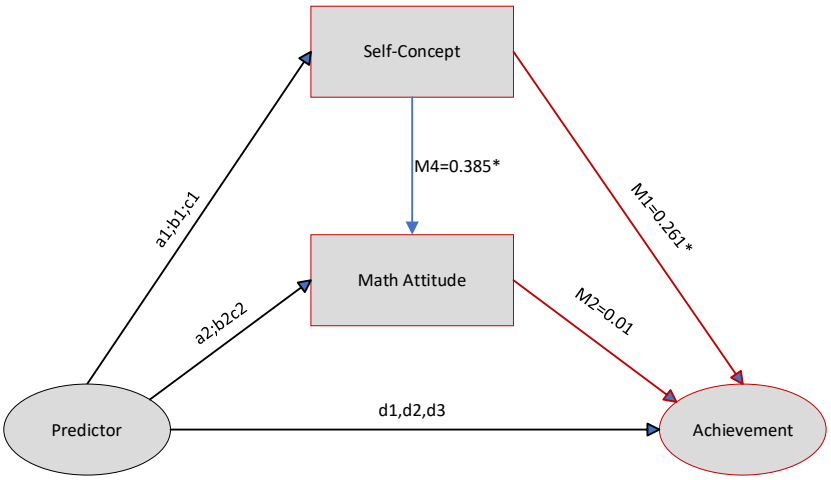

Fig. 9: Another serial mediation path; *: P-value <0.05

Table 17 shows the serial path effects from each predictor on achievement through Math attitude to self-concept mediators, and the total effect of each construct is recalculated with the corresponding p-value. It appears that a significant serial mediation effect from all predictors through the causal path from Math attitude to self-concept (M4) on Math achievement (p-value<0.01) Comparing the total effects shown in Table 17 with the totals in Tables 14, 15, and 16, both results in the different serial mediation paths are significant at (p-value<0.01), with a slight effect difference.

Table 17: Serial mediation and total effects of another suggested path

Path effects from math attitude → self-concept	Serial path	Effect	P-value	Total	P-value
Teacher concept	a2M4M1	0.0304	0.001*	0.2253	0.001*
School bullying	b2M4M1	-0.0034	0.001*	-0.3117	0.001*
School connectedness	c2M4M1	0.0225	0.001*	-0.0683	0.001*

*: P-value <0.05

4. Discussion and conclusion

Table 13 shows that the direct effect of the self-concept mediator on achievement is positive and significant, unlike the Math attitude mediator, which has an insignificant effect on achievement. This finding is compatible with the finding mentioned in Boe's study that sometimes, in the presence of self-

concept, the effect of the Math attitude could be declined (Boe et al., 1999). In addition, as Eccles and Wigfield (2002) concluded in the EVT, sometimes the expectancy beliefs (self-concept) stay significant predictors, whereas values (Math attitude) become not significant predictors when both are used simultaneously to predict achievement (Meece et al., 1990; Wigfield and Eccles, 1992). Moreover, Michaelides et al. (2019) illustrated that all motivation variables correlate with achievement, but when modeled together, their relative importance could vary, and they may interact.

Although all the predictors have a significant effect on Math attitude, the specific parallel indirect effect of each predictor through the Math attitude mediator is insignificant. All the predictors have a significant specific parallel indirect effect through self-concept mediator and a significant direct effect on achievement, which means that self-concept is partially mediating teacher concept, school bullying, and school connectedness on achievement in the grade 4 model.

Within the two mediators, a significant and positive causal path is shown from self-concept to Math attitude and vice versa. Since all the serial mediation effects through the causal path from the self-concept to Math attitude are insignificant, we tested another serial path through Math attitude to self-concept, and it was significant for all three predictors. All total effects are slightly different but significant in both models (with different serial paths), which means that the serial effect from self-concept to Math attitude or the serial effect from Math attitude to self-concept has an almost similar effect in total. The school bullying construct has the highest effect on Math achievement in total, while the school connectedness has the least in the grade 4 model.

These results were consistent with previous studies that showed a significant impact of self-confidence, bullying, school connection, and teacher perception on student achievement (McMahon et al., 2009; Michaelides et al., 2019; Rutkowski et al., 2013; Mullis et al., 2020). This study revealed that self-confidence is a very important factor that directly and indirectly affects student achievement.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Abu-Hilal MM, Abdelfattah FA, Alshumrani SA, Abduljabbar AS, and Marsh HW (2013). Construct validity of self-concept in TIMSS's student background questionnaire: A test of separation and conflation of cognitive and affective dimensions of self-concept among Saudi eighth graders. European Journal of Psychology of Education, 28: 1201-1220. https://doi.org/10.1007/s10212-012-0162-1

Ahmad S, Zulkurnain N, and Khairushalimi F (2016). Assessing the validity and reliability of a measurement model in structural equation modeling (SEM). British Journal of Mathematics and Computer Science, 15(3): 1-8. https://doi.org/10.9734/BJMCS/2016/25183

Alghamdi B, Khadawardi H, Alghamdi B, Almathami K, Alshimai A, Alqahtani M, Alanazi H, Alfawaz F, Alodhaibi S, and Talukder M (2022). Key performance indicators for measuring sustainable performance: A case study of implementing Saudi Arabia's Vision 2030 strategy. Performance Improvement Quarterly, 34(4): 491-519. https://doi.org/10.1002/piq.21359

Alghamdi N (2021). TIMSS 2019 report-First insights into mathematics and science achievements of Saudi Arabia students in grades 4 and 8 in an international context. International Association for the Evaluation of Educational Achievement, Amsterdam, Netherlands.

Alotaibi NB (2019). Cyber bullying and the expected consequences on the students' academic achievement. IEEE Access, 7: 153417-153431. https://doi.org/10.1109/ACCESS.2019.2947163

Alshaikh AA (2021). A proposal for developing the performance of intermediate second-grade students in science tests in trends in international mathematics and science study (TIMSS). Journal of Education and e-Learning Research, 8(1): 26-33. https://doi.org/10.20448/10.20448/journal.509.2021.81.26.33

Boe EE, Turner III HM, May H, Leow CS, and Barkanic G (1999). The role of student attitudes and beliefs about mathematics and science learning in academic achievement: Evidence from TIMSS for six nations. Data Analysis Report No. 1999-DAR3, Center for Research and evaluation in social policy, University of Pennsylvania, Philadelphia, USA.

Byrne BM (2011). Structural equation modeling with Mplus: Basic concepts, applications, and programming. 1st Edition, Routledge, New York, USA.

Civelek ME (2018). Essentials of structural equation modeling. Lulu Press, Morrisville, USA. https://doi.org/10.13014/K2SJ1HR5

Deci EL and Ryan RM (2013). Intrinsic motivation and self-determination in human behavior. Springer Science and Business Media, Berlin, Germany.

Eccles JS and Wigfield A (2002). Motivational beliefs, values, and goals. Annual Review of Psychology, 53(1): 109-132. https://doi.org/10.1146/annurev.psych.53.100901.135153 **PMid:11752481**

Elsayed MA, Clerkin A, Pitsia V, Aljabri N, and Al-Harbi K (2022). Boys' underachievement in mathematics and science: An analysis of national and international assessment data from the Kingdom of Saudi Arabia. Large-scale Assessments in Education, 10: 23. https://doi.org/10.1186/s40536-022-00141-9

Fakeeh KA (2016). KSA 2030 vision (Kingdom of Saudi Arabia's 2030 project) and its focus on families and students. International Journal of Computer Applications, 149(1): 46-48. https://doi.org/10.5120/ijca2016911345

Fornell C and Larcker DF (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18(1): 39-50. https://doi.org/10.1177/002224378101800104

Hattie J (2008). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. Routledge, London, UK.

Hox JJ, and Bechger TM (1998). An introduction to structural equation modeling. Family Science Review, 11: 354-373.

Khine MS (2013). Application of structural equation modeling in educational research and practice. Volume 7, Sense Publishers, Rotterdam, Netherlands. https://doi.org/10.1007/978-94-6209-332-4

Lee J and Shute VJ (2010). Personal and social-contextual factors in K–12 academic performance: An integrative perspective on student learning. Educational Psychologist, 45(3): 185-202. https://doi.org/10.1080/00461520.2010.493471

Martin MO, Von Davier M, and Mullis IVS (2020). Methods and procedures: TIMSS 2019 technical report. Retrieved from Boston College, TIMSS & PIRLS International Study Center. Available online at: https://timssandpirls.bc.edu/timss2019/methods

McMahon SD, Wernsman J, and Rose DS (2009). The relation of classroom environment and school belonging to academic self-efficacy among urban fourth-and fifth-grade students. The Elementary School Journal, 109(3): 267-281. https://doi.org/10.1086/592307

Meece JL, Wigfield A, and Eccles JS (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. Journal of Educational Psychology, 82(1): 60-70. https://doi.org/10.1037//0022-0663.82.1.60

Mercier H and Sperber D (2017). The enigma of reason. Harvard University Press, Cambridge, USA. https://doi.org/10.4159/9780674977860

Michaelides MP, Brown GT, Eklöf H, and Papanastasiou EC (2019). Motivational profiles in TIMSS mathematics: Exploring student clusters across countries and time. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-26183-2

Mullis IV and Martin MO (2017). TIMSS 2019 assessment frameworks. International Association for the Evaluation of Educational Achievement, Amsterdam, Netherlands.

Mullis IV, Martin MO, Foy P, Kelly DL, and Fishbein B (2020). TIMSS 2019 international results in mathematics and science. International Association for the Evaluation of Educational Achievement, Amsterdam, Netherlands.

Rutkowski L, Rutkowski D, and Engel L (2013). Sharp contrasts at the boundaries: School violence and educational outcomes internationally. Comparative Education Review, 57(2): 232-259. https://doi.org/10.1086/669120

Ryan RM (1998). Commentary: Human psychological needs and the issues of volition, control, and outcome focus. In: Heckhausen J and Dweck CS (Eds.), Motivation and self-regulation across the life span: 114–133. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511527869.006

Said H, Badru BB, and Shahid M (2011). Confirmatory factor analysis (CFA) for testing validity and reliability instrument in the study of education. Australian Journal of Basic and Applied Sciences, 5(12): 1098-1103.

Steinmayr R, Weidinger AF, Schwinger M, and Spinath B (2019). The importance of students' motivation for their academic achievement–Replicating and extending previous findings. Frontiers in Psychology, 10: 1730. https://doi.org/10.3389/fpsyg.2019.01730 **PMid:31417459 PMCid:PMC6685139**

Tighezza MH (2014). Modeling relationships among learning, attitude, self-perception, and science achievement for grade 8 Saudi students. International Journal of Science and Mathematics Education, 12: 721-740. https://doi.org/10.1007/s10763-013-9426-8

Von Davier M (2019). TIMSS 2019 scaling methodology: Item response theory, population models, and linking across modes. In: Martin MO, Von Davier M, and Mullis IV (Eds.), Methods and procedures: TIMSS 2019 technical report: 11.1-11.25. International Association for the Evaluation of Educational Achievement, Amsterdam, Netherlands.

West SG, Taylor AB, and Wu W (2012). Model fit and model selection in structural equation modeling. In: Hoyle RH (Ed.), Handbook of structural equation modeling: 209–231. The Guilford Press, New York, USA.

Wigfield A and Eccles JS (1992). The development of achievement task values: A theoretical analysis. Developmental Review, 12(3): 265-310. https://doi.org/10.1016/0273-2297(92)90011-P