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Article

A PREDICTIVE PLS-SEM MODEL OF MATHEMATICS ACHIEVEMENT: IMPLICATIONS FOR EDUCATIONAL DATA ANALYTICS AND INTELLIGENT DECISION SUPPORT

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Abstract: This study develops and validates a predictive PLS-SEM model that explains mathematics achievement through the interaction of students' math mindsets, grit, and learning disposition, providing an analytical framework for educational decision-making. A positive attitude toward math is crucial as it develops students' perseverance, influences their approach to learning, and greatly improves their performance in the subject. This research ultimately investigates the indirect effects of students' perseverance and attitudes on the link between their mathematical mindsets and their performance. The participants in this research comprised 360 high school students selected from ten different schools within the Pampanga Division, representing various types of schools. These students were chosen using stratified proportional sampling to ensure a fair and accurate representation across different school categories. The results showed that students fixed and growth mindsets related to mathematics significantly impact their levels of perseverance, attitude, and overall achievement in the subject. Furthermore, the findings revealed that students' perseverance and attitudes towards mathematics have both direct and indirect effects on their performance in math. In light of these results, it can be concluded that mathematical perseverance and attitude play an important mediating role in the relationship between students' mindsets and their academic success in mathematics. A growth mindset by itself is insufficient, perseverance and a positive attitude are vital for transforming beliefs into consistent academic effort and achievement. Therefore, educators should promote perseverance and attitude alongside mindset to enhance long-term achievements in mathematics. The findings extend beyond mathematics education by contributing to the fields of computer information systems, predictive analytics, and intelligent decision support. The validated PLS-SEM model demonstrates how advanced computational modeling techniques can transform educational data into predictive insights that support evidence-based decision-making and performance optimization. As a data-driven analytical framework, the model has potential applications in educational information systems, learning analytics platforms, and academic management systems for identifying students at risk, guiding targeted interventions, and enhancing institutional decision-making. These contributions highlight the growing role of computational intelligence and predictive analytics in addressing complex educational challenges through information systems and analytical modeling.
Keywords: Grit, Disposition, Math Mindsets, Achievement.

1. Introduction

Educational institutions increasingly rely on data-driven decision-making to improve learning outcomes, making predictive analytics and intelligent modeling essential tools in educational management. By integrating educational data analytics with Partial Least Squares Structural Equation Modeling (PLS-SEM), this study develops a predictive model that explains how students' grit and mathematical disposition mediate the relationship between mathematical mindsets and achievement, providing an analytical framework for evidence-based educational interventions. The influence of positive psychology on students' characteristics, actions, and educational results is receiving increased attention. The behaviors of students that either aid or hinder the accomplishment of their goals are influenced by a mix of cognitive and noncognitive elements. Positive psychology focuses on concepts and approaches concerning personality traits like grit, mindset, and various forms of perfectionism.

Students' mathematical grit is the specific subject of this study. Sriraman and English (2020) assert that mathematical grit refers to a student's tenacity and consistent work when addressing difficult mathematical tasks. It entails retaining drive and concentration in the face of obstacles, demonstrating a growth-oriented approach to math education. Students who possess significant mathematical grit are more likely to accept challenging assignments, grow from their errors, and keep trying to solve them. According to research, grit in mathematics greatly enhances academic achievement and problem-solving abilities. Resilience and long-term success in kids' mathematical journeys can be fostered in classrooms by encouraging mathematical gritawareness in exercising active participation in the execution of greening initiatives.

The increasing adoption of intelligent decision support systems (IDSS) in education has transformed how institutions analyze student data, predict academic outcomes, and formulate evidence-based interventions. Unlike conventional decision-making approaches that rely primarily on descriptive statistics or historical academic performance, intelligent decision support systems integrate predictive analytics, computational modeling, and advanced analytical techniques to generate actionable insights from multidimensional datasets. In this context, the present study demonstrates the applicability of Partial Least Squares Structural Equation Modeling (PLS-SEM) as an intelligent analytical framework capable of modeling the complex interrelationships among students' mathematical mindset, grit, mathematical disposition, and mathematics achievement. By identifying both direct and indirect pathways influencing academic performance, the proposed predictive model provides educators, school administrators, and policy makers with a robust decision-support mechanism for early identification of students at risk of underachievement, personalized instructional planning, strategic resource allocation, and continuous monitoring of learning outcomes. Furthermore, the integration of cognitive and non-cognitive variables into a unified predictive framework enhances the capability of educational information systems to move beyond simple performance reporting toward intelligent forecasting and intervention planning. Such an approach strengthens learning analytics by enabling institutions to anticipate students' academic needs, optimize teaching strategies, and design targeted support programs that improve educational effectiveness.

Although numerous studies have established the independent relationships among mathematical mindset, grit, mathematical disposition, and mathematics achievement, limited research has simultaneously examined these constructs within a comprehensive predictive framework that accounts for both their direct and indirect effects. Most previous investigations have relied on conventional statistical techniques that primarily test isolated relationships rather than modeling the complex interactions among latent cognitive and non-cognitive variables. Furthermore, there remains a paucity of studies employing Partial Least Squares Structural Equation Modeling (PLS-SEM) to develop and validate predictive models capable of supporting evidence-based educational decision-making. Addressing this gap, the present study integrates mathematical mindset, grit, and mathematical disposition into a unified PLS-SEM model to explain mathematics achievement, thereby contributing to educational data analytics, computational modeling, and predictive learning analytics by providing a robust analytical framework for understanding and predicting students' academic performance.

This study contributes to the fields of computer information systems, educational data analytics, and industrial management applications by demonstrating the use of Partial Least Squares Structural Equation Modeling (PLS-SEM) as a predictive modeling technique for analyzing complex educational data. The proposed structural model advances the application of computational analytics by integrating cognitive and non-cognitive constructs into a unified predictive framework capable of explaining mathematics achievement. The findings extend the use of PLS-SEM beyond traditional educational research by providing a validated analytical model that supports data-driven decision-making, intelligent educational management, and learning analytics. Furthermore, the study offers a scalable predictive framework that may be integrated into educational information systems, academic performance monitoring platforms, and decision support systems to facilitate early identification of learning needs, optimize instructional interventions, and enhance institutional planning. Consequently, the research bridges educational psychology with computational modeling and information systems, demonstrating the value of advanced analytical methodologies in solving real-world educational management problems.

2. MEHODS

The researcher used a quantitative research approach specifically Complex Correlational Design. A complex correlational design is a research approach that examines the relationships among multiple variables simultaneously, often involving both quantitative and categorical data. Unlike simple correlational studies that focus on the relationship between two variables, complex correlational designs assess how several variables interrelate, providing a more comprehensive understanding of the data (Jhiangani et al., 2015). This design allows researchers to explore more intricate patterns, such as mediation, moderation, or indirect effects among variables. This design is appropriate in this study since it investigates not only direct effects but also indirect effects of the variables used in the study. Furthermore, PLS-SEM was used since it supports complex models, works well with small samples, emphasizes prediction, and accommodates various construct types — all relevant to educational research involving psychological traits and academic outcomes.

The respondents in this study were 360 selected High School Students enrolled from 10 different schools in the Division of Pampanga which is higher than the computed minimum sample of 300 to ensure adequate power and reliable results, particularly when using bootstrapping methods, which are often used to assess indirect effects for mediation analysis with multiple mediators (Preacher & Hayes, 2008). Three schools for each class namely small (n = 80), medium (n= 100), and large schools (n=140) (including 1 high school managed by State Universities and Colleges (n = 40) were considered in this study. Power analysis was utilized to calculate the sample size with the accepted minimum significance level (α) of 0.05 and accepted minimum level of power β of 0.80 (Pilot and Hungler, 1999). The medium effect size of 0.15 was calculated based on Cohen's f2 formula, a common measure of estimating the effect size. In selecting the respondents of the study, a proportional stratified sampling technique was utilized. This was used to guarantee a proportional representation of sample respondents from different types of schools.

The instruments used in this study are as follows:

Math Mindset Scale. Dweck (1999) created the general mindsets measure, which has six items with a 6-point Likert scale ranging from "strongly disagree" to "strongly agree." There are three items for growth mindset, while the remaining three is for the fixed mindset. Whereas a fixed mindset maintains that a person's intellectual capacity remains constant despite their best efforts, a growth mindset contends that intellectual capacity can be increased via hard work. This scale produces two distinct scores: one for a fixed mindset and the other for a growth mindset. The Cronbach's alpha reliability scores for growth and fixed mindset were determined to be α=0.81 and α=0.70, respectively in the study of Beyaztas and Hymer (2018)

Academic Grit Scale in Mathematics. It is 10-item scale measuring students' `academic grit specifically in mathematics which was developed by Clark and Malecki (2019) which is now the new version of short grit scale originally developed by Duckworth and Quinn (2009). The scale has ten 5-point Likert-type items, 1 being 'not at all like me' and 5 being 'very much like me'.

Mathematical Disposition Assessment Tool. Kamid et al. (2021) created this questionnaire that consists of 18 statements. It is a 4-Point Likert Scale ranging from 1 (Strongly Disagree) to 4 (Strongly Agree). It has a CVI value of 1.00 and Cronbach Alpha Coefficient of 0.75).

Mathematical Achievement Scale. It is a 20-item questionnaire developed by Kusmaryono et al., (2021) will be used in the study. It has subscales such as confidence (3 items), flexibility (3 items), usefulness (3 items), perseverance (3 items), curiosity (3 items), appreciation (3 items) and metacognition (2 items). The scale has twenty 5-point Likert-type items, 1`strongly disagree' and 5 being 'strongly agree'.

3. RESULTs

1. Respondents` Level of Math Mindsets, Grit, Disposition and Performance

Table 1: Descriptive Analysis of the Effect of Students` Growth Math Mindset to their Mathematical Grit, Disposition, and Performance

Hypotheses	*β*	*p*	*SE*	*F^2*	*Decision*
Direct effects					
H_1. Growth Mindset → Mathematical Grit	0.678	<0.001	0.041	0.211	Accepted
H_2. Growth Mindset → Math Disposition	0.478	<0.001	0.0365	0.156	Accepted
H_3. Growth Mindset → Math Achievement	0.536	<0.001	0.044	0.123	Accepted
H_4. Fixed Mindset → Mathematical Grit	-0.254	<0.001	0.042	0.034	Accepted
H_5. Fixed Mindset → Math Disposition	-0.199	<0.001	0.035	0.031	Accepted
H_6. Fixed Mindset → Math Achievement	-0.313	<0.001	0.043	0.048	Accepted

The findings revealed that students demonstrated a high level of growth mindset in mathematics (M = 3.17, SD = 0.60) and a low level of fixed mindset (M = 1.91, SD = 0.64). This indicates that, on average, students believe their mathematical ability can improve with effort, practice, and effective strategies. At the same time, they tend to reject the belief that mathematical ability is fixed or innate. Limeri et al., (2020) concluded in their study that a student with high growth mindset leads to low level of fixed mindset in their academics

The most beneficial aspect of the mathematics mindset profile is its impact on the motivation, engagement and success more profoundly than ever imagined. The area of low fixed mentality suggests that learners possess the opposite belief to the broader stereotype in the mathematics education discourse who regard success in mathematics as a prerogative of a select few 'naturally gifted' persons. An effort to change this specific mindset increases engagement with educational tasks and lessens worry. Students with a mathematically motivated growth mindset not only engaged and achieved more advanced goals; these were the findings by Boaler et al. (2018). That work underscores the importance of countering the mindset encouraging a belief of fixed ability in mathematics, confirming that fostering a greater participation and lower anxiety in the context of mathematics classrooms will happen if a growth mindset is nurtured.

In addition, students exhibited notable grit with an average score of (M = 3.18, SD = 0.88), disposition (M = 3.08, SD = 0.72), and performance in mathematics (M = 4.16, SD = 0.91). This suggests students possess the stamina to learn and resolve mathematical problems for extended durations, regardless of challenges, lack of satisfaction, or frustrations they might face. It combines extraordinary, sustained success in mathematics with grit, discipline, achievement, an unwavering work ethic, deep commitment, and fervent zeal. In addition to this, students show strong average beliefs and habits toward mathematics which enhances learning and productivity. It exemplifies how a student approaches mathematical problems, thinks about mathematics, and values arithmetic in education and daily experiences. To conclude, students with high proficiency in mathematics tend to have a well-developed grasp, appreciation, and ability to efficiently execute and tackle mathematical concepts and problems. This corroborates the findings of the research study of Archide (2024) on the correlation between grit, disposition towards mathematics, and the performance in mathematics of Grade 11 students which concluded that students with higher mathematical disposition and grit performed better in mathematics, indicating that these are strong determinants of academic achievement in mathematics. This bears some relation to the findings by Estrella and Boholano (2022) where a moderate positive significant correlation between grit and mathematical ability was reported, and it was concluded that the enduring focus on an overarching goal along with stubborn determination could improve one's mathematical abilities.

2. Results of Direct Effects of Growth and Fixed Mindsets of Students to their Grit, Disposition, and Achievement in Mathematics

Table 2: Results of the Hypotheses Testing (Direct Effects)

Hypotheses	*β*	*p*	*SE*	F^2	*Decision*
Direct effects					
H_1. Growth Mindset → Mathematical Grit	0.678	<0.001	0.041	0.211	Accepted
H_2. Growth Mindset → Math Disposition	0.478	<0.001	0.0365	0.156	Accepted
H_3. Growth Mindset → Math Achievement	0.536	<0.001	0.044	0.123	Accepted
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H_5. Fixed Mindset → Math Disposition	-0.199	<0.001	0.035	0.031	Accepted
H_6. Fixed Mindset → Math Achievement	-0.313	<0.001	0.043	0.048	Accepted

The results of the study revealed **growth mindset of students has a positive and significant impact to their grit, disposition, and performance in mathematics** while fixed mindset has a negative and significant impact to the said outcome variables. Thus, H3, H4, H5 and H6 are accepted. These results are aligned with the findings by Kaya & Karakoç (2022) which observed an increasing deliberative math mindset had a positive indirect impact on math achievement through academic grit, whereas a fixed math mindset had no impact. This highlights the importance of fostering students' growth mindsets in order to enhance their perseverance and math achievement. Developing strong behavioral skills and developing a positive attitude toward mathematics are deeply connected to adopting a growth mindset. Students who genuinely believe that their skills can improve with effort and practice are more willing to face difficulties and stay optimistic about math. This mindset boosts their confidence, interest, and engagement, which enhances their understanding and contributes to academic achievement. On the contrary, a fixed mindset stifles perseverance and the willingness to attempt to engage with and approach challenges in a defeatist manner. This aligns with Dweck's work and suggests that teaching strategies aimed at fostering "growth mindsets" can enhance resilience, motivation, and performance in math. According to Dong et al. (2023), a growth mindset was found to have an indirect positive impact on achievements in mathematics through intrinsic motivation, favorable failure attributions, and self-efficacy in mathematics. In contrast, a fixed mindset negatively impacted achievement in mathematics through heightened anxiety relating to the subject and low self-efficacy.

fixed mindset primarily affects students' attitudes toward mathematics by increasing anxiety, reducing confidence, and decreasing interest in the subject. It causes many students to underestimate the importance of mathematics, leading them to disengage altogether. According to Dweck (2006), a fixed mindset fosters negative emotions towards effort and perseverance, resulting in anxiety and low self-esteem, which undermine psychological well-being and belief in one's abilities. Over time, these negative perceptions reduce classroom participation and learning engagement. Consequently, students with a fixed mindset tend to perform poorly in math because they are less inclined to put in effort, seek assistance, or adopt effective strategies. Supporting this, Davis et al. (2020) found that a fixed mindset can lead to feelings of helplessness when faced with setbacks, which diminishes mathematics self-efficacy. This decrease in self-confidence further contributes to negative attitudes toward math and hampers academic achievement.

3. RESULTS OF DIRECT EFFECTS OF MATHEMATICAL GRIT AND DISPOSITION OF STUDENTS TO THEIR MATH ACHIEVEMENT

Table 3: Results of the Hypotheses Testing (Direct Effects)

Hypotheses	*β*	*p*	*SE*	*F^2*	*Decision*
Direct effects					
H_7 Mathematical Grit→ Math Achievement	0.319	<0.001	0.031	0.094	Accepted
H_8. Math Disposition→ Math Achievement	0.348	<0.001	0.038	0.076	Accepted

Results revealed that both mathematical grit and disposition of students have a positive and significant impact to their math achievement having p-values less than 0.01 level of significance, hence H7 and H8 are accepted. This only shows that the mathematical achievement of students can be attributed to their mathematical grit and disposition. Moreover, higher level of mathematical grit and disposition means higher level of mathematical achievement and vice versa.

This only implies that in order to improve pupils' performance in mathematics, this study emphasizes the significance of mathematical grit and a positive mathematical disposition. While grit helps students overcome challenges, a positive attitude characterized by disposition and curiosity promotes active participation and strategic thinking. When combined, these qualities form a potent force that inspires students to overcome difficulties and strengthens the idea that practice and hard work are the keys to progress. Based on the findings, grit and disposition—two non-cognitive traits—are just as important for succeeding in mathematics as cognitive abilities. Thus, the goal of education should be to cultivate these qualities in learning environments that are growth-oriented and supportive.

4. RESULT OF INDIRECT EFFECTS OF MATHEMATICAL GRIT AND DISPOSITION OF STUDENTS TO THE RELATIONSHIP BETWEEN THEIR MATH MINDSETS AND ACHIEVEMENT

Table 4: *Model fit and Quality Indices*

Index	Coefficient
Average Path Coefficient (APC)	= 0.257, P<0.001
Average R-squared (ARS)	= 0.482, P<0.001
Average Adjusted R-squared (AARS)	= 0.474, P<0.001
Average Block VIF (AVIF)	= 3.021, acceptable if ≤5, ideally ≤3.30
Average Full Collinearity (AFVIF)	= 3.152, acceptable if ≤5, ideally ≤3.30
Tenenhaus GoF (GoF)	= 0.396, small >0.1, medium >0.25, large >=0.36
Simpson's Paradox Ratio (SPR)	= 0.814, acceptable if ≥0.70, ideally = 1
R-Squared Contribution Ratio (RSCR)	= 0.908, acceptable if ≥0.90, ideally = 1
Statistical Suppression Ratio (SSR)	= 0.998, acceptable if >0.70
Nonlinear Bivariate Causality Direction Ratio (NLBCDR)	= 0.998, acceptable if ≥0.70

Table 4 presents the model fit and quality indices of the structural equation model (SEM). Results showed the average path coefficient (APC=0.257), Average R-squared (ARS=0.482), and the Average Adjusted R-squared (AARS=0.474) with significant p-values of <0.001. The Average Block VIF (AVIF=3.021) and Average Full Collinearity Coefficient (AFVIF=3.152) showed acceptable results based on the acceptable interval implying that there is no pathological collinearity, and no common bias is observed in the model. Results also revealed that the model results with a large effect size that exceeded a Tenenhaus GOF rate of 0.396 (GOF= 0.396). Results also demonstrated an acceptable coefficient (acceptable if 0.9, ideally if =1) on Simpson's Paradox Ratio (SPR=0.814), R-squared Contribution Ratio (RSCR=0.908) and likewise showed an acceptable value greater than 0.7 (>0.7) on Statistical Suppression Ratio (SSR=0.998) and an acceptable Nonlinear Bivariate Causality Direction Ratio (NLBCDR= 0.998) 0.7. ≥≥

Table 5: Convergent Validity and Reliability Measures

Construct/Item (Reflective)	Item Loading	p-value	AVE	CR	CA
Math Mindsets					
Math Growth Mindset (mgm)					
- *mgm1*	0.820	<0.001			
- *mgm2*	0.826	<0.001			
- *mgm3*	0.819	<0.001	0.589	0.870	0.841
- *mgm4*	0.832	<0.001			
- *mgm5*	0.829	<0.001			
Math Fixed Mindset (mfm)					
- *mfm1*	0.854	<0.001			
- *mfm2*	0.839	<0.001	0.571	0.892	0.855
- *mfm3*	0.863	<0.001			
- *mfm4*	0.800	<0.001			
- *mfm5*	0.802	<0.001			
Mathematical Grit *(mgrit)*					
- *mgrit1*	0.878	<0.001			
- *mgrit2*	0.862	<0.001			
- *mgrit3*	0.822	<0.001			
- *mgrit4*	0.834	<0.001			
- *mgrit5*	0.830	<0.001	0.675	0.927	0.899
- *mgrit6*	0.852	<0.001			
- *mgrit7*	0.840	<0.001			
- *mgrit8*	0.837	<0.001			
- *mgrit9*	0.823	<0.001			
- *mgrit10*	0.820	<0.001			
Math Disposition *(mdisp)*					
- *mdisp1*	0.835	<0.001			
- *mdisp2*	0.821	<0.001	0.651	0.903	0.891
- *mdisp3*	0.825	<0.001			
- *mdisp4*	0.802	<0.001			
- *mdisp5*	0.823	<0.001			
- *mdisp6*	0.825	<0.001			
- *mdisp7*	0.843	<0.001			
- *mdisp8*	0.837	<0.001			
- *mdisp9*	0.820	<0.001			
- *mdisp10*	0.822	<0.001			

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- *mdisp9*	0.820	<0.001			
- *mdisp10*	0.822	<0.001			

The researcher systematically evaluated cross-loadings and excluded indicators that exhibited minimal loading differences across constructs to ensure the robustness of discriminant validity and construct reliability. This process aligns with the recommendations of Fawad (2021), who emphasized that eliminating such indicators can enhance discriminant validity. Likewise, Cohen et al. (2003) and Farrell (2010) proposed that the removal of problematic items can improve the overall measurement structure. After removing these indicators, the model demonstrated satisfactory discriminant and convergent validity, with all factor loadings and average variance extracted (AVE) values exceeding the minimum threshold of 0.50 and achieving statistical significance at the 0.05 level as shown in Table 5.

To assess the internal consistency and reliability of the refined constructs, the researcher presented the composite reliability (CR) and Cronbach's alpha (CA). Based on the standards set by Fawad (2021), Hair et al. (2022), and Rasoolimanesh (2021) as cited in Paras (2023), values exceeding 0.70 indicate acceptable reliability. The results confirmed that all CR and CA values were above this benchmark, thereby affirming that the measurement model meets the established criteria for both validity and reliability.

Table 6: Results of the Hypotheses Testing (Indirect [mediator] Effects)

Hypotheses	*β*	*p*	*SE*	*F²*	*Decision*
Indirect effects (mediator)					
H_9. Growth Mindset → Mathematical Grit → Math Achievement	0.387	<0.001	0.052	0.231	Accepted
H_{10}. Fixed Mindset → Mathematical Grit → Math Achievement	-0.372	<0.001	0.163	0.202	Accepted
H_{11}. Growth Mindset → Math Disposition → Math Achievement	0.382	<0.001	0.057	0.260	Accepted
H_{12}. Fixed Mindset → Math Disposition → Math Achievement	-0.390	<0.001	0.160	0.200	Accepted

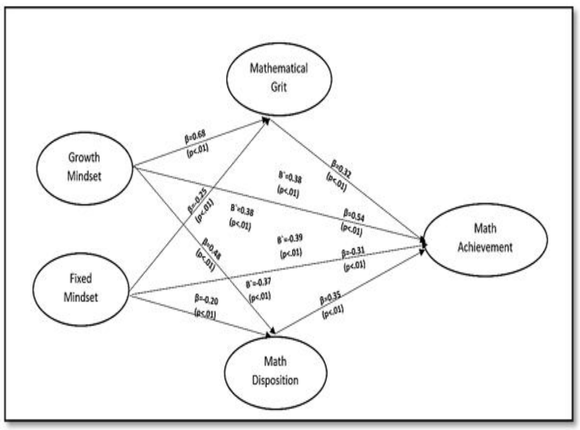

Figure 2. Structural Model with Beta Coefficients

The results showed that mathematical grit is a critical mediator of students' mindsets (either growth or fixed) and their performance in mathematics, thus confirming hypotheses H9 and H10. It is important to understand that growth mindsets enable individuals to believe that skills can improve over time, and it is grit – defined as the persistence of challenge or consistent endeavor toward a goal – that turns this belief into action. As Yu et al. (2021) illustrated, math-specific grit not only determines the outcome, but also mediates the relationship between math anxiety and math achievement, underscoring the importance of sustained effort in persistent challenges. Moreover, motivation resulting from a growth mindset may fizzle out in the absence of grit. Curiously, grit also has the potential to help individuals with a fixed mindset endure difficult tasks, which can be seen as undermining the notion that abilities are set in stone. These are the findings reported by Correa-Rojas et al. (2023), which examined inverse relationships between academic self-efficacy, grit, a growth mindset, and academic performance in research conducted with students from Peruvian universities. Ultimately, the findings underscore the necessity to cultivate positive, growth-focused mindsets alongside grit in order to foster resilience, increased effort, and improved mathematical performance. Zhao et al. also supports these findings. In their study, (2024) found that grit mediates the relationship between a growth mindset and learning-related subjective well-being in students, suggesting that a growth mindset may support well-being through grit. Moreover, these findings indicate that mathematical disposition serves as a critical mediating factor between both growth and fixed mindsets and students' mathematics achievement. People with a growth mindset believe that with effort, abilities can improve. To engage actively and sustain effort, however, a positive mathematical disposition—which I call a proactive mathematical attitude—is essential. Such a disposition improves a student's ability to face challenges, employ problem-solving approaches, remain engaged, and attain favorable outcomes. Even students who possess a fixed mindset can benefit from having a strong mathematical disposition because it enables them to counteract self-defeating attitudes by fostering resilience and active engagement. A strong mathematical disposition therefore mediates the relationship between mindset and performance by transforming both growth and fixed mindsets into positive action, especially toward achievement in mathematics. This supports the findings of Aquino and Ibarra (2025), who reported that mathematical disposition, self-efficacy, and self-perseverance were significantly and positively correlated with mathematics performance, emphasizing the value of a positive disposition for achievement. Moreover, Sangco (2021) stated that improved students' disposition towards mathematics had a positive effect on their creative thinking in the subject which, indicates an encouragement enables better attitude towards problem solving and academics in general.

The Full Collinearity Variance Inflation Factor (VIF) on Table 5 was utilized to identify and address common method variance in the SEM results. Constructs are considered free from common method bias when their VIF values are below 3.3, which was confirmed in this study, meeting the common method bias test criteria (Kock, 2015). The analysis also examined predictive validity (q^2) and the coefficient of determination (r^2). An r^2 value below 0.02 indicates a very weak effect, which is not practically relevant (Chicco et al., 2021). However, the r^2 values for growth mindset ($r^2 = 0.441$), fixed mindset ($r^2 = 0.459$), and math achievement ($r^2 = 0.652$) showed moderate to strong effects. Additionally, the Stone-Geisser q^2 coefficient must exceed zero to demonstrate the predictive relevance of a variable (Hair et al., 2013 & Hair et al., 2011). Within this study, it was observed that all q^2 coefficients exceeded zero, hence satisfying the conditions for both r^2 and q^2.

Table 7: Common Method Bias, Predictive Relevance, and Coefficient of Determination

	Full Collinearity VIF	Q2	R2
Mathematical Grit	**2.749**		
Growth Mindset	2.855	0.324	0.441
Fixed Mindset	2.970	0.363	0.459
Math Achievement	2.876	0.439	0.652
Math Disposition	**2.648**		
Growth Mindset	2.887	0.332	0.441
Fixed Mindset	2.783	0.343	0.459
Math Achievement	2.813	0.397	0.652

4. CONCLUSIONS

Based on the study's results, it can be concluded that both mathematical grit and disposition significantly mediate the influence of students' mindsets on their mathematical achievement. A growth mindset alone does not lead to achievement; instead, it must be paired with a sufficient level of grit that enables sustained effort toward reaching the goal. Grit helps even students with a fixed mindset succeed academically, despite their limited beliefs about their potential. Similarly, a positive mathematical disposition facilitates the development of engagement, confidence, resilience, and effective learning behaviors. Even students with fixed mindsets can benefit from strong dispositions that foster curiosity and focused attention. The findings emphasize the interconnected relationships among mindsets, dispositions, grit, and their combined effects on performance. Consequently, educators should prioritize cultivating students' grit and mathematical disposition alongside encouraging growth mindsets to promote long-term success, especially in mathematics. Future research could explore additional mediators or moderators such as academic self-efficacy, math anxiety, or teacher feedback. Additionally, educational policies should support social-emotional learning frameworks that teach and apply components of grit and mindset, particularly in mathematics.

Implications of the Study on Educational Data Analytics and Intelligent Decision Support

This study contributes to the fields of educational data analytics, computational modeling, predictive analytics, intelligent decision support systems, and information systems by demonstrating the application of Partial Least Squares Structural Equation Modeling (PLS-SEM) in developing a predictive model of mathematics achievement. The validated model illustrates how latent psychological constructs, such as mathematical mindset, grit, and mathematical disposition, can be analyzed to generate evidence-based insights for academic planning and intervention.

The findings highlight the potential of advanced multivariate modeling techniques to transform educational data into actionable information that supports data-driven decision-making, learner performance prediction, and instructional improvement. Furthermore, the study provides a scalable analytical framework that can be integrated into learning analytics, educational management systems, and artificial intelligence-assisted educational applications to facilitate early identification of students requiring academic support and optimize teaching and learning strategies.

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