



Psychological Determinants of Mathematics Achievement Among Saudi Students: Evidence from PISA 2022

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ABSTRACT

Mathematics performance reflects a complex interaction of psychological (emotional), social, motivational, and structural factors; however, prior research has typically examined these variables in isolation, limiting understanding of their combined effects, particularly within Middle Eastern contexts. This study investigates the relative impact of emotional, social, motivational, and structural variables on mathematics achievement among Saudi students using data from PISA 2022. A cross-sectional design was employed with a nationally representative sample of 6,928 students, and mathematics achievement was measured using ten plausible values. Hierarchical regression analysis was conducted to assess the incremental contribution of psychological variables beyond gender and socio-economic status. The findings suggest that mathematics anxiety was the strongest psychological predictor of achievement ($\beta = -0.185$, $p < .001$), while school belonging demonstrated a weak positive effect ($\beta = 0.038$, $p = .008$). In contrast, motivation was not statistically significant ($\beta = -0.021$, $p = .123$), and life satisfaction showed a weak negative association with achievement ($\beta = -0.051$, $p < .001$). The inclusion of psychological variables increased the explained variance by 3.6% ($f^2 = 0.041$). These results suggest that emotional processes, particularly mathematics anxiety, play a central role in shaping academic performance beyond structural factors, whereas motivation may operate indirectly. The findings underscore the importance of prioritizing interventions that target mathematics anxiety, as such approaches are likely to yield greater improvements in academic outcomes than strategies focusing solely on motivation or general well-being, consistent with the educational priorities outlined in Saudi Arabia's Vision 2030.

KEYWORDS

Behavioral science; mathematics achievement; mathematics anxiety; PISA 2022; school belonging.

INTRODUCTION

Mathematics performance is widely regarded as a key indicator of educational success within an education system because of its significant influence on the acquisition of critical skills in logic, problem-solving, and preparedness for life in the twenty-first century (Abadiga et al., 2026). From the point of view of the behavioral sciences, mathematics performance is a tangible consequence of the complex interaction between numerous cognitive, affective, social, and environmental antecedents, which makes it an important focus of cross-disciplinary studies. Beyond cognitive processes, recent studies demonstrate that the impact of several other factors on mathematics performance, including psychological and environmental ones (Eccles & Wigfield, 2002; OECD, 2023).

Regarding mathematics education, the learner engagement is not only influenced by cognitive capacity but also by the formation of their mathematical identity and involvement in mathematical practices. The mathematical identity is defined through the learners' perceptions of their competence, valuing of mathematics, and sense of belonging in mathematics. The engagement in mathematical practices refers to reasoning, problem-solving, and communication in mathematics. Both are composed of affective and cognitive processes that are gaining attention in explaining the differences in achievement in mathematics (Martin, 2000; OECD, 2023).

Of the various behavioral systems that have been studied extensively in the behavioral science literature, there are four which comprise distinct yet interconnected categories. These include affective processes (mathematics anxiety), social processes (sense of school belonging), motivational processes (learning motivation), and evaluative processes (life satisfaction). They play a crucial role in determining how students engage with learning-related activities and cope with them. They are particularly important in cognitively challenging areas like math because they determine the degree to which a student is able to persist, concentrate, and cope with academic pressures (Eccles & Wigfield, 2002).

Although many international studies have been conducted, recent systematic reviews and meta-analyses continue to underscore the importance of mathematics anxiety, motivation, and other psychological processes in shaping mathematics achievement (Barroso et al., 2021; Liu et al., 2026; Vu et al., 2024). Current views in behavioral sciences highlight the significance of developing models on how different behavioral systems work together in structured settings, considering the recent findings that have suggested that more than one emotional system is involved in learning mathematics at the same time (Schoenherr et al., 2025). Although recent studies using PISA 2022 data have examined the relationships among learning environments, mathematics anxiety, motivation, and mathematics achievement in Gulf Cooperation Council (GCC) countries, these factors have primarily been investigated within contextual or domain-specific frameworks rather than through an integrated behavioral science perspective (Al-Mutawah et al., 2025).

However, the combined impact of all these systems, which are made up of affective, social, and motivational systems, requires further research with regard to nationally representative samples of Middle Eastern countries through large-scale assessment test data that allows for multivariate behavioral analysis. The availability of nationally representative data due to the results of the PISA 2022 cycle of Saudi Arabia provides an opportunity to explore how these systems operate together to influence the performance of the students in terms of their math achievement (OECD, 2024). It should be noted that although there have been several studies regarding individual factors affecting the academic performance of students, limited evidence exists regarding their combined impact.

The current study is intended to help bridge that research gap by examining the degree to which certain psychological predictors such as motivation, school belongingness, anxiety in math, and overall life satisfaction are predictive of variations in math performance for Saudi students. The study's contribution to the research literature may be viewed from three perspectives: (a) how it assesses the contribution of multiple psychological factors using an integrated model, (b) the calculation of effect size estimates so that comparisons may be made with respect to behavior, and (c) the creation of generalizable findings for Saudi Arabia.

In addition, the study contributes to behavioral science by proposing a hierarchical framework of behavioral factors that offers a structured way to understand emotions, motivation, and social influences in academic performance.

Behavioral Mechanisms Under Investigation

Math anxiety, consistent with the Control–Value Theory by Pekrun (2006), is expected to have an adverse effect on performance through two major routes: (a) a reduced ability to focus during problem solving; and (b) avoidance of math-related activities. On the other hand, following the Belongingness Theory by Goodenow (1993), school belonging is expected to affect academic achievement positively via two major routes: (a) increased engagement behaviors, including greater efforts and persistence in facing challenging tasks; and (b) shielding from anxiety. ESCS can be considered a structural variable which may affect one's access to certain behavioral variables such as educational assistance and academic opportunities. Hence, the objective of the study is to test the mediating role of affective and social processes in math achievement.

Behavioral Science Theoretical Framework and Hypothesized Model

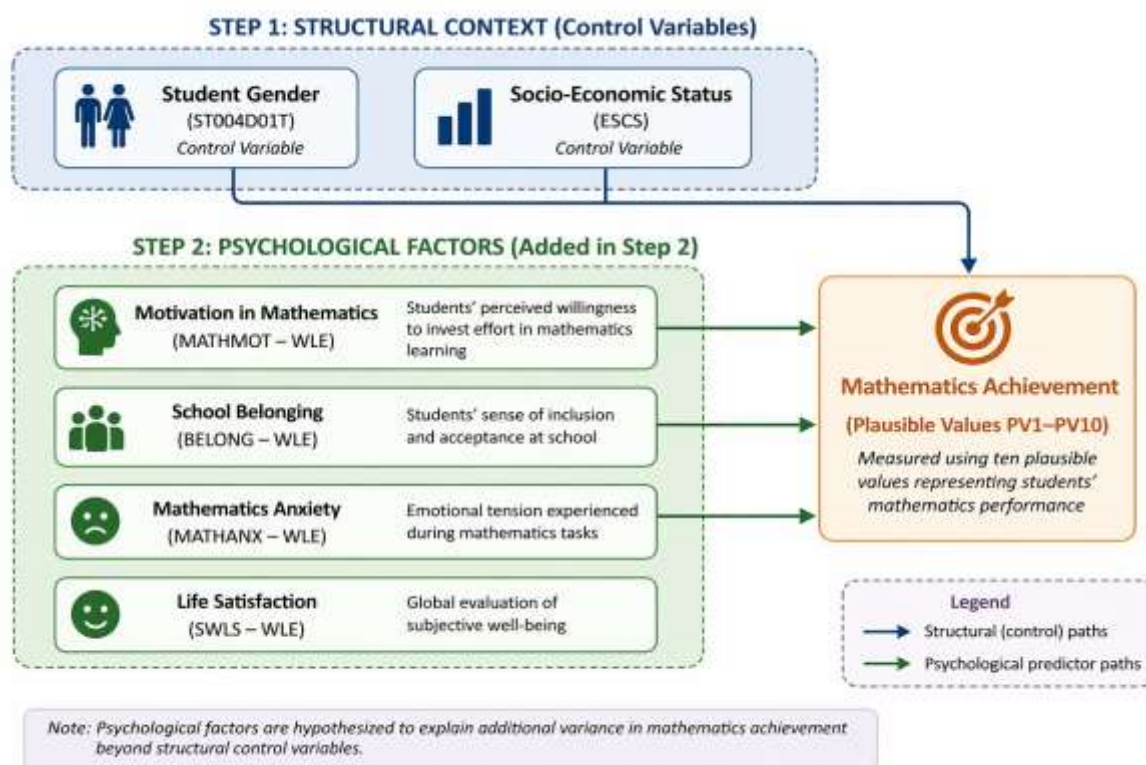
The following paper is based on four different but interconnected theoretical paradigms of behavioral science that help understand the connection between psychological variables and mathematical performance. According to the theory of Expectancy-Value (Eccles & Wigfield, 2002), motivational processes are seen as a combination of one's expectation and value placed on a particular activity. Similarly, the concept of Control-Value Theory (Pekrun, 2006) allows interpreting math anxiety as an emotional variable connected to lack of control over academic assignments and high task value, resulting in inefficiency while solving problems.

Further, Belongingness Theory (Goodenow, 1993) proposes that a feeling of belonging facilitates involvement and emotional security, which in turn leads to academic achievement. Moreover, from a broader perspective, the Ecological Systems Theory (Bronfenbrenner, 1979) situates the above psychological elements within nested environmental systems, emphasizing socio-economic status among the various structural influences on resource availability.

The integration of these theories provides a behavioral science framework that uses a multi-system approach to the study of behavioral science, having three major hypotheses. First, affective systems, such as math anxiety, influence cognitive behavior due to their consumption of working memory (Ashcraft & Krause, 2007). Second, social systems, such as attachment to schools, can influence academic behavior directly and indirectly through anxiety. Third, structural systems, such as socio-economic class, control access to resources needed for the development of self-regulatory behaviors. In this research, the focus is placed on the direct influences mentioned above, through a hierarchical regression analysis. The conceptual model derived from this integrated behavioral science framework is presented in Figure 1.

Figure 1.

The Analytical Model in the study



The model represents a multilevel behavioral system in which structural factors define the context, while affective and social processes operate as proximal mechanisms influencing performance.

Research Hypotheses

H1: Mathematics anxiety (affective process) negatively predicts mathematics achievement.

H2: School belonging (social process) positively predicts mathematics achievement.

H3: Motivation (motivational process) does not retain a significant independent effect on mathematics achievement when affective and social processes are controlled.

H4: School belonging negatively predicts mathematics anxiety, supporting the hypothesized emotional buffering mechanism.

H5: Mathematics anxiety negatively predicts mathematics achievement.

H6: Socio-economic status (structural factor) positively predicts mathematics achievement and accounts for a substantial proportion of variance relative to psychological predictors.

Collectively, these hypotheses represent contributions to behavioral science as a whole. These hypotheses contribute to behavioral science because they identify an empirical hierarchy of the behavioral determinants of academic success and reveal the greater influence of affective processes relative to motivational processes.

LITERATURE REVIEW

The literature reviewed in this section is organized around the principal behavioral systems hypothesized to influence mathematics achievement. More specifically, the study examines the motivational, affective, social, evaluative, and structural dimensions of mathematics learning and integrates these perspectives into a unified behavioral science framework. This progression provides the theoretical foundation for the study's hypotheses and proposed analytical model.

Motivation and Mathematics Achievement

Motivation has been well documented as a key variable influencing academic performance (Deif et al., 2026). In line with Expectancy–Value Theory, students' academic performance is shaped by their expectations of success and the value they assign to academic tasks (Eccles & Wigfield, 2002). Accordingly, the more important students perceive a subject such as mathematics to be, the more motivated they are likely to be to engage with it.

However, empirical findings have shown variation in both the nature and strength of this relationship. Some studies report strong associations between motivation and achievement, whereas others suggest that motivation operates indirectly through mediating variables such as engagement and academic self-concept (Marsh & Martin, 2011). This variability indicates that motivation is not an isolated predictor but rather one of multiple interrelated factors influencing academic performance.

From a behavioral science perspective, motivation is conceptualized as a distal predictor of performance that operates through proximal processes such as engagement, effort regulation, and persistence. Behavioral science gives an adequate account for the reason behind the existence of poor or insignificant relationships between motivation and achievement when the latter two variables are placed in a single model.

Mathematics Anxiety

One of the most widely researched psychological variables is mathematics anxiety, which is always found to have a negative correlation with student achievement in mathematics learning

(Dawood et al., 2016; Hembree, 1990). It involves experiencing tension and uneasiness while carrying out activities related to mathematics.

Research demonstrates that math anxiety affects working memory operations necessary for problem-solving (Ashcraft & Krause, 2007; Dundas et al., 2009). The meta-analysis proves that there is a significant correlation between anxiety and failure results (Barroso et al., 2021; Peleg-Popko et al., 2003). Some other evidence indicates that the lack of attention and efficient cognitive performance are consequences of anxiety, which leads to poor academic achievements (Finell et al., 2022; Huang, 2025). Moreover, extensive research shows that the highest scores among the students were relatively low in math tests due to high anxiety levels (Ewell et al., 2022; OECD, 2015).

The behavioral processes that link anxiety to performance can be explained through three key areas, including: (a) avoidance behavior, which restricts practice and involvement with tasks; (b) cognitive distraction, particularly working memory impairment while problem-solving; and (c) physiological arousal, which might impact executive functions adversely (Lobman, 2014). The behavioral processes mentioned above are applicable in many fields; nevertheless, their importance cannot be denied in mathematics due to the heavy involvement of reasoning and working memory (Ashcraft & Krause, 2007; Finell et al., 2022).

School Belonging

The feeling of school belongingness refers to how accepted the students feel in their educational setting and is correlated positively with improved engagement, motivation, and perseverance in education (Bryk et al., 2010; Goddard et al., 2000; Hoy et al., 2006).

According to empirical evidence, students who possess a high level of sense of belonging tend to perform better in terms of their academic success (Aguirre Muñoz et al., 2025; Goodenow, 1993; Lee & Smith, 1999). Furthermore, current research shows that the sense of belonging can have an indirect impact on students' success due to its ability to minimize negative emotions, including anxiety (Asanjarani et al., 2024).

From a behavioral standpoint, there are two ways by which school belongingness works: (a) the direct way by improving engagement, participation, and help-seeking behavior, and (b) the indirect way by reducing anxiety and corresponding avoidance behavior. The dual pathway model implies that the effects of belonging can act independently or be mediated through the effects on academic performance in behavioral models (Asanjarani et al., 2024; Goddard et al., 2001; Goodenow, 1993).

Life Satisfaction

Life satisfaction constitutes a holistic assessment of general well-being (Diener et al., 1985). Although it may be linked to general adaptability and resilience, it tends not to be related directly to academic success. Large scale studies have found that the effect of life satisfaction becomes less significant in the presence of socio-economic structural factors (OECD, 2023). Hence, life satisfaction can be seen as a distal predictor as opposed to being a domain-based predictor for students' performance.

In behavioral science, satisfaction with life is viewed as an evaluative construct at a broad domain level and is not similar to the emotional construct that is related to mathematics. Thus, the lower correlation between satisfaction with life and mathematics performance is expected theoretically. At this point, satisfaction with life serves as a discriminator in that domain-specific measures like math anxiety predict outcomes better.

Although the preceding sections focus on the psychological determinants of mathematics achievement, these processes operate within broader structural and contextual conditions that shape students' educational opportunities and behavioral development. Accordingly, the following section examines the role of the socio-economic context as a complementary factor influencing academic achievement.

Structural and Contextual Influences

Socio-economic background continues to be among the most persistent factors related to school success (Lee & Bryk, 1989). It affects the availability of various resources and educational possibilities (OECD, 2023). In addition, recent studies show that psychological factors interact with other aspects instead of functioning separately (Nilsen & Gustafsson, 2014).

Socio-economic status impacts behavioral tendencies via several mechanisms, which are discussed below: (a) availability of cognitive resources such as books, study materials, and tutors; (b) behavioral role modeling by parents in terms of their expectations and support for education; and (c) lack of continuous stress, which normally leads to depletion of self-regulation capabilities. All these factors work hand-in-hand with psychology and somewhat separately, making it essential for hierarchical models to be built with a structural variable-first approach (Al joudeh & Elyan, 2026; OECD, 2023).

Taken together, the preceding evidence suggests that mathematics achievement is shaped by multiple interconnected behavioral and contextual processes. However, most previous studies have examined these factors in isolation rather than as components of an integrated system. The following section synthesizes these perspectives to develop the integrated behavioral science framework underpinning the present study.

Behavioral Science Integration and the Present Study

Although past studies have linked personality characteristics and mathematics performance, most of these studies have focused on single variable relationships within certain paradigms. This narrow focus is detrimental to comprehension because it makes it difficult to evaluate the functioning of more than one behavior system at the same time.

The use of the integrated behavioral systems approach helps mitigate this deficiency through studying affective (mathematics anxiety), social (school belonging), motivational (learning motivation), and evaluative (life satisfaction) dimensions in a single analysis framework. However, the implementation of such a methodology for the study of mathematics education in Saudi Arabia has been largely neglected.

This research aims to fill this gap through an examination of (a) how much uniquely accounted variance is attributable to each behavior dimension after accounting for structural

covariates, (b) the effect size of affective, social, and motivational constructs, and (c) the proportion of variance accounted for by psychological mechanisms beyond socio-economic determinants. An integrative analysis of behavior makes possible the comparison of effect size among the different dimensions.

This research study examines the proposed integrative framework using hierarchical regression analysis, which assesses the independent contribution of each behavior to the variance accounted for.

METHODOLOGY

Research Design

The current research utilized the descriptive correlational predictive research design. The choice of this design is justified by its appropriateness in studying correlations among various psychological and contextual variables, but without manipulating any of them. However, one should realize that the descriptive correlational predictive design cannot be used for drawing any conclusions about causality. Nonetheless, with the help of hierarchical regression analysis, one can explore incremental correlations between certain variables, which confirms the existence of their association.

Whereas hierarchical regression analysis constitutes an established analysis procedure, the utilization of this method in the current study satisfies criteria for a well-executed quantitative analysis process in the way that: (a) the method utilizes theoretically ordered blocks of variables, which include structural and psychological variables, (b) the results provide information regarding incremental variance explained (ΔR^2) together with effect sizes (Cohen's f^2), (c) the results consider multicollinearity and other regression assumptions, and (d) the causal implications of the regression model are clearly outlined. It can be stated that this type of data analysis is applicable for examining the influence of behavioral dimensions on students' mathematical achievements. Although hierarchical regression was appropriate for addressing the objectives of the present study, future research could employ multilevel modeling or structural equation modeling to account more explicitly for the hierarchical structure of PISA data and to examine the direct and indirect relationships among psychological constructs. The present study applies hierarchical regression analysis to a large-scale international assessment dataset to examine the incremental contribution of psychological variables beyond structural factors.

Data Source and Sample

Secondary data were employed for the analysis, specifically the Programme for International Student Assessment 2022. The data were sourced from the OECD database. The initial Saudi Arabia PISA 2022 dataset contained a national-level representative sample of 15-year-old students ($N = 6,928$). However, missingness in some psychological variable data resulted in different sample sizes when using various regression models for data analysis. Following this procedure across all variables included in the analysis (sex, socio-economic status composite

index, motivation, school belonging, mathematics anxiety, and life satisfaction), the final sample size for regression models was $N = 5,385$. This constituted around 77.7% of the original sample.

The approximately 22% reduction in the sample was therefore attributable to incomplete questionnaire responses rather than the exclusion of participants based on substantive characteristics. Although listwise deletion reduced the effective sample size, it ensured that all regression estimates were based on a consistent set of complete observations while avoiding the additional assumptions associated with imputing missing data.

Sampling Procedure

PISA utilizes a stratified two-stage sampling strategy. The initial stage involves the random selection of schools through probability proportionate to size sampling in the context of strata defined by geographical location and school type. The second stage involves the random selection of students from the selected schools.

While PISA incorporates a sophisticated sampling strategy, the analyses included here did not make use of sampling weights to test relationships conservatively. Unweighted analysis yields unbiased point estimates, yet may generate biased (underestimated) standard errors. It is therefore imperative that statistical significance be cautiously interpreted, with nonsignificance being doubly so.

Study Variables

Ten plausible values (PV1MATH–PV10MATH) served as indicators for the latent variable of mathematics achievement. Plausible values are repeated draws from the posterior distribution of student ability and are intended to deliver an unbiased estimate of the population of interest. Statistical analyses were performed for each plausible value separately, and the findings were then combined. The independent variables were multi-faceted behavioral constructs, measured via the PISA student questionnaire. Students perceived motivation toward learning mathematics was indicated by their tendency to put effort into studying mathematics (MATHMOT). School belongingness was used as a proxy for the social system (BELONG, WLE), while mathematics anxiety (ANXMAT, WLE) represented the affective system and was measured as an indicator of psychological stress experienced during mathematics classes or assignments. Finally, students' life satisfaction (SWBP, WLE) was used as an indicator of subjective well-being (evaluative system). These variables were estimated based on Item Response Theory (IRT)-derived Weighted Likelihood Estimates (WLE). Gender was kept constant, where males were assigned code 0 and females code 1 (ST004D01T). Another control variable used was socio-economic status (ESCS), a combined indicator of economic, social, and cultural capital. The predictors were standardized in order to make comparison easier between the standardized regression coefficients (β) (mean = 0, standard deviation = 1).

Data Preparation Procedures

The preparation of the data involved an elaborate procedure comprising several stages. Initially, the PISA 2022 dataset was obtained from the OECD database. Afterward, the dataset was filtered for the Saudi Arabia subsample based on the CNT variable. Then, the variables that

would be used in the analysis were selected and included the following: mathematics achievement (PV1MATH–PV10MATH); motivation (MATHMOT); school belonging (BELONG); mathematics anxiety (ANXMAT); life satisfaction (SWBP); socio-economic status (ESCS); and gender (ST004D01T). Patterns of missing data were examined for all the variables before the analysis. Subjects who had missing values on any of the study variables were dropped from the sample using listwise deletion, leaving a sample size of $N = 5,385$. Missing data were not imputed in order to avoid introducing assumptions regarding the underlying mechanisms of missingness. While this approach is methodologically conservative, it may have reduced statistical power and limited the generalizability of the findings.

Statistical Analysis Procedures

Statistical analyses were conducted sequentially. First of all, the means and standard deviations for all the dependent variables were produced using descriptive statistics. The use of the weighted likelihood estimation procedure allowed generating indexes according to international standards. Next, bivariate correlations between math performance and the identified behavioral dimensions were computed by employing Pearson's correlation coefficients, where the missing data problem was addressed via pairwise deletion approach. Finally, an appropriate theoretical behavioral model consisting of two steps was used. In Step 1 (Model 1), the effects of control variables, namely gender and socio-economic status (ESCS), were controlled, whereas behavioral variables, including motivation, school belonging, math anxiety, and life satisfaction, were used in Step 2 (Model 2).

In accordance with the guidelines set by PISA, results from the ten different analyses performed were aggregated using the method of calculating mean coefficients and consistency checks to ensure the validity of the results generated by the study. Effect sizes for the variables in the study were determined using their effect on variance explained (ΔR^2) and f^2 according to the guidelines by Cohen. All the necessary assumptions were tested before carrying out the analysis. Tests for multicollinearity were carried out using variance inflation factors (VIF), and tests for linearity were carried out using partial regression plots.

All the analyses were carried out using IBM SPSS Statistics software, and syntax files are provided on request from the corresponding author. To account for the hierarchical structure of PISA data, cluster-robust standard errors were estimated using school identification codes, adjusting for intra-school dependencies in observations. The results of the cluster-robust estimation are reported in the footnotes of Table 5. The same pattern of statistical significance was observed, indicating that the findings are robust to clustering effects.

Ethical Considerations

The secondary dataset used for this research was provided through the Programme for International Student Assessment and was completely anonymized and available to the public. Since this dataset has been completely anonymized and is readily available to the public, it did not require any ethics approval or informed consent.

RESULTS

The findings from this study using the 2022 PISA cycle data of Saudi Arabia are presented in this section. The analyses will be classified into descriptive statistics, correlations, and hierarchical regression analysis. The number of valid responses varied across variables due to missing data in the student survey. Consequently, sample sizes differed across analyses ($N = 5,385$ to $N = 6,550$). All regression models were estimated using complete-case data ($N = 5,385$).

Levels of Psychological Variables Among Saudi Students

Means and standard deviations were calculated for all psychological variables using available cases. Results are presented in Table 1.

Table 1.

Descriptive Statistics of Psychological Variables

Variable	N	Mean	SD	95% CI (Lower)	95% CI (Upper)
Motivation in Mathematics	5949	0.06	0.23	0.054	0.066
School Belonging (WLE)	6505	0.01	1.02	-0.015	0.035
Mathematics Anxiety (WLE)	5816	0.10	1.22	0.069	0.131
Life Satisfaction (WLE)	5385	0.64	1.52	0.599	0.681

Values near zero correspond to the international standardization process used by PISA (OECD average = 0, standard deviation = 1). The psychological characteristics of Saudi students thus conform to international norms. Nevertheless, there are larger standard deviations in mathematics anxiety (standard deviation = 1.22) and life satisfaction (standard deviation = 1.52).

Relationships Between Psychological Variables and Mathematics Achievement

Correlation coefficients for Pearson were calculated to study the interrelationship between psychological factors and mathematical performance. The findings are shown in Table 2.

Mathematics anxiety shows the strongest correlation with mathematics achievement ($r = -.206$). This suggests that there exists a relatively strong negative correlation compared to others. There is also a slight positive correlation with school belonging ($r = .103$). Motivation is significant statistically, even though it is very weak ($p = .015$). There is no significant correlation between life satisfaction and mathematics achievement.

Table 2.

Correlations with Mathematics Achievement

Variable	r	p	95% CI (Lower)	95% CI (Upper)
Motivation	-0.032	0.015	-0.057	-0.007
School Belonging	0.103	<0.001	0.079	0.127
Mathematics Anxiety	-0.206	<0.001	-0.231	-0.181
Life Satisfaction	0.015	0.120	-0.012	0.042

Note. Unweighted correlations. Standard errors could be underestimated because of the complex survey design used in PISA, which was not incorporated into the analysis.

Contribution of Control Variables

Hierarchical regression analysis was performed to assess the effect of demographic factors on mathematics performance. The findings of Model 1 are shown in Table 3.

Table 3.

Model 1 (Control Variables Only)

Variable	B	β	t	p
Gender	6.98	0.053	3.88	<0.001
ESCS	17.04	0.275	20.18	<0.001

Model Fit: $R^2 = 0.080$

Mathematics performance is explained by socio-economic status and gender to the extent of 8%. The socio-economic status proves to be the most influential indicator because its effect size ($\beta = 0.275$) considerably outweighs that of the gender indicator. Variance Inflation Factor (VIF) values fell between 1.01 and 1.15, suggesting that multicollinearity is not a concern.

Incremental Contribution of Psychological Variables

The addition of psychological variables was examined using hierarchical regression. Results are presented in Table 4.

Table 4.

Model Comparison

Model	R^2	ΔR^2	p
Model 1	0.080	—	<0.001
Model 2	0.116	0.036	<0.001

The inclusion of behavioral systems increased the explained variance in mathematics achievement by 3.6%.

Effect Size:

Cohen's $f^2 = 0.041$

The effect size ($f^2 = 0.041$) indicates a small contribution of psychological variables beyond structural controls.

Note. While listwise deletion has been the main method for analysis, the fairly high percentage of retained data (77.7%) implies that there is little chance of bias due to missing data. Other studies conducted on this data could consider multiple imputation as an option.

Key Psychological Predictors of Mathematics Achievement

Regression models were run separately using all ten plausible values (PV1 to PV10), and their findings were then averaged out. There was consistency among the plausible values regarding their coefficients.

Mathematics anxiety, which is part of the affective system, proves to be the most powerful behavioral indicator of mathematics performance, with a large negative impact ($\beta = -0.185$, $p < .001$). School belonging reveals a slight but significant relationship ($\beta = 0.038$, $p = .007$). Motivation fails to exhibit an independent significant effect on the mathematics score in a multivariate setting ($\beta = -0.021$, $p = .134$). Life satisfaction indicates a weak negative relationship with mathematics performance ($\beta = -0.051$, $p < .001$).

Table 5.*Pooled Regression Results Across Plausible Values*

Variable	β	SE	95% CI	T	p	B
Motivation	-0.021	0.014	[-0.048, 0.006]	-1.50	0.134	-5.73
School Belonging	0.038	0.014	[0.010, 0.066]	2.71	0.007	2.42
Mathematics Anxiety	-0.185	0.014	[-0.212, -0.158]	-13.21	<0.001	-9.82
Life Satisfaction	-0.051	0.014	[-0.078, -0.024]	-3.64	<0.001	-2.16

Note. Cluster-robust standard errors (adjusting for school-level clustering) were estimated but did not change the pattern of statistical significance for any predictor. Results are available from the corresponding author.

Interpretation of the Suppression Effect

Another important pattern that can be observed relates to the relationship between life satisfaction and math performance, where the former does not have any correlation with the latter ($r = .015$, $p = .120$), but has a negative coefficient in the regression analysis ($\beta = -0.051$, $p < .001$).

Behavioral sciences indicate that once the effect of the common variance between socio-economic status and other psychological factors is accounted for, the part of life satisfaction that remains unique becomes negatively related to achievement. This means that the two can be independent or contradictory with each other, taking into consideration the structural advantages. This result should be taken with caution and further research is needed before any action can be taken.

DISCUSSION

In this research, an analysis of the relationship between psychological and structural variables and mathematical achievement among Saudi students was conducted using the Programme for International Student Assessment data from 2022. The findings provide a holistic behavioral science perspective to understanding the impact of different factors in shaping academic success.

Relative Effect Sizes Across Behavioral Domains

The model used for behavioral science testing in this study allows for comparison of effect sizes between various aspects. According to the findings, it is apparent that structures have the most impact on the acquisition of mathematical skills (socio-economic status: $\beta = 0.275$). This is followed by affect, social process, and motivation ($\beta = -0.185$, $\beta = 0.038$, and $\beta = -0.021$ respectively).

A hierarchical framework comprising structural, affective, social, and motivational enables researchers to systematically evaluate the extent to which different behavioral precursors contribute to human behavior. This study adds to research in the field of behavioral

science through demonstrating that the relative importance of psychological aspects varies greatly; and, further, demonstrates that affective factors consistently outweigh motivational factors when explaining performance-based behaviors. The magnitude of mathematics anxiety is approximately two-thirds that of socio-economic status in explaining students' educational outcomes. This finding highlights that emotional variables may exert an influence on academic performance comparable to structural factors. These results are consistent with Pekrun's (2006) Control-Value Theory, which posits that achievement emotions play a central role in academic performance. Empirical evidence further suggests that anxiety impairs working memory and cognitive efficiency, thereby reducing performance (Ashcraft & Krause, 2007; Finell et al., 2022).

In terms of behavioral science, these findings suggest that interventions targeting affective processes could yield meaningful improvements in academic performance, even if they do not fully offset structural inequalities. In contrast, social influences, including school belonging, show relatively small effect sizes, while motivational constructs do not exhibit independent predictive value once the other variables are controlled for.

Mechanisms of Motivational Processes

An important outcome of this study is that there was no statistically significant relationship found for motivation with math performance when analyzing using multiple regression ($\beta = -.02$, $p = .12$) even though Expectancy- Value theory would predict such a positive correlation (Eccles & Wigfield, 2002). This result should also be viewed with caution since the results could potentially indicate an indirect effect of motivation.

From a behavioral science viewpoint, motivation seems to work through mediated channels, especially because of its association with emotion-related and engagement-related mechanisms. When both affective factors (mathematics anxiety) and social factors (belongingness in schools) are incorporated into the model, the uniqueness of the effect of motivation becomes trivial. This reasoning agrees with the views presented by Marsh and Martin (2011), who state that motivational constructs work reciprocally rather than having an independent influence on outcomes. Based on the findings from these studies, it may be concluded that motivational-based programs alone have little success compared to the programs which address issues concerning emotions. For example, when the math anxiety of a student is alleviated, his motivation can be increased through better perception of his competence levels and less avoidance tendencies (Lowe, 2019).

Domain Specificity in Behavioral Prediction

The findings from the life satisfaction tests are extremely important in terms of gaining insight into the idea of domain specificity in the context of behavioral research. Although there was no association between life satisfaction and mathematics scores ($r = 0.015$, $p = 0.120$), there was an inverse association in the case of multiple regression ($\beta = -0.051$, $p < .001$).

This suggests that, after controlling for socio-economic status and other psychological variables, the unique variance in life satisfaction is negatively associated with mathematics achievement. However, this result should not be interpreted as indicating that higher levels of

life satisfaction reduce academic performance. Instead, this pattern may reflect a statistical suppression effect, in which the shared variance among life satisfaction, socio-economic status, and other psychological variables is partialled out, leaving a residual association that may differ in direction from the zero-order correlation.

Theoretically speaking, life satisfaction is an assessment of one's general well-being, and not a specific construct related to a particular field like academics (Diener et al., 1985). Therefore, life-satisfied students may achieve their well-being through different facets of life like family connections, social relations, or even recreation, which do not have any connection with high performance in mathematics. On the other hand, specific constructs like math anxiety have a direct relationship with learning and academic success. Accordingly, the observed negative regression coefficient should be interpreted with caution, as it likely reflects the complexity of multivariate relationships and statistical suppression rather than a direct negative effect of life satisfaction on mathematics achievement.

This interpretation is also in agreement with the notion of life satisfaction as a general evaluation indicator (Diener et al., 1985), as well as with evidence pointing to the lack of significance of its impact once the context is controlled for (OECD, 2023). Nonetheless, the link between achievement and particular domain variables like math anxiety or school bonding seems more reliable. These findings emphasize the significance of ensuring that the assessment domain is consistent with outcome specificity, and the drawbacks associated with using measures of overall well-being to predict academic success.

Structural and Behavioral Interactions

The findings indicate that, socio-economic status remains the most effective factor that influences students' achievements in math, as was confirmed by OECD (2023) and other researches concerning education discrepancies. Still, in spite of this information, high effect size regarding math anxiety proves that psychological factors also matter a lot.

The behavioral approach offers an answer in that while there is some influence from structure in the environment in which behavior occurs, structure cannot control the outcome of the processes. Emotional reactions to the process of learning, such as anxiety, can have a bearing on the outcome despite structures in place. These findings suggest that consideration of both structural and behavioral approaches should be incorporated when formulating policies.

Saudi Educational Context and Policy Implications

These findings should be interpreted within the context of education reforms being carried out in Saudi Arabia, particularly through Vision 2030 that places much importance on enhancing the quality and competitiveness of education. While infrastructure is key, the present findings indicate the importance of taking behavior into account.

From a behavioral science perspective, three intervention priorities emerge:

1. Mathematics anxiety reduction interventions, including expressive writing, growth mindset approaches, and formative assessment practices designed to reduce evaluation-related stress and cognitive interference.

2. School belonging interventions targeting behavioral engagement, including teacher professional development, structured peer collaboration, and mentoring programs.
3. Monitoring of domain-specific behavioral indicators, such as anxiety and belonging, alongside achievement outcomes within national assessment systems.

These suggestions are based on the effect size gradient that indicates the possibility of higher gains from interventions that target anxiety rather than only motivation or wellness. Another result that merits mention is that in contrast to the international trend toward narrowing gender gaps in math or even reversing the trend to favor females, female students in this study demonstrated higher scores than male students ($\beta = 0.053$, $p < .001$). These results may indicate particularities inherent to the Saudi education system, such as the segregated instruction and/or assessments conducted for males and females. It is necessary for future researchers to investigate whether this relationship varies among genders in this context.

Limitations of the Study

A few limitations need to be considered while considering these results. In terms of methodology, first, the cross-sectional nature does not allow drawing conclusions about causality between variables, such as anxiety and academic performance. Another limitation related to the study methodology is that the study was based on PISA results, reflecting post-pandemic educational practices. Behavioral science-based limitations are as follows:

- (a) using self-reports instead of behavioral observation measures (e.g., persistence, asking for help, or avoiding situations linked to math), which implies the presence of common method bias;
- (b) lack of measures capturing anxiety physiologically or in an experimental manner; and (c) inability to assess temporal order of behavior. Moreover, the study conducted within a specific national context makes the results less externally valid; therefore, the same findings should be investigated in other countries.

Contribution to Behavioral Science Knowledge

In terms of contributions to the body of knowledge in behavioral science, this paper makes its contribution in three main ways. Firstly, this research is able to provide some empirical data on the relative effect sizes of four sets of factors affecting math success. Secondly, it illustrates the superiority of the use of measures of behavior specific to a certain domain over more general measures. Lastly, it is able to provide an effect size hierarchy among all of the sets of factors analyzed here (structural > affective > social > motivational). The study expands knowledge on how psychological and contextual factors interact to affect academic achievement by combining several behavioral categories in one model using national sample data, and lays the groundwork for further investigations that utilize more sophisticated methods.

CONCLUSIONS

The findings indicate that the effect sizes for mathematics ability in adolescents of Saudi Arabia follow the order: socioeconomic status ($\beta = 0.275$), mathematics anxiety ($\beta = -0.185$), school belonging ($\beta = 0.038$), and motivation (no significance). Moreover, there is an additional 3.6% variance accounted for by psychological variables than structural ones ($f^2 = 0.041$).

The findings presented above offer empirical support for a unified behavioral science theory where: (a) affective variables such as math anxiety directly affect performance; (b) social variables such as school connectedness affect indirectly through engagement and protective emotional pathways; (c) motivational variables affect indirectly through intermediary variables; and (d) well-being does not predict achievement. The development of such a theory would help determine the importance of different behavioral domains within the framework of a comprehensive theory.

Regarding public policy considerations, it can be noted that the effect size gradient discussed above has relevance to the educational reforms currently taking place in Saudi Arabia, which are based on Vision 2030. The interventions that will involve addressing the issue of math anxiety using expressive writing, growth mind-set interventions, and formative assessment will certainly have more impact than interventions geared toward motivation or general well-being. However, the interventions for improving school belongingness should still be conducted alongside the other interventions.

Further studies need to be carried out that examine the mediation processes using structural equation modeling and analyze if there are gender differences in the gender-segregated educational systems of Saudi Arabia. The use of behavioral observation along with self-reporting will also improve the quality of data collected from participants. Therefore, reducing the level of math anxiety is currently the best way to enhance math performance in Saudi Arabia. This research has established a hierarchy of effect sizes within the realm of behavior, thus it provides a solid base for improving behavioral science theories and designing interventions.

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