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Optimization of the motivation for success in mathematics at higher education: Evidence from novel graph-based visualization of three models

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Abstract
Using three mathematical models, this study aims to optimize students' motivation for success in courses of mathematics at universities. The uniqueness of this study is crystalized in the novel graphical visualization of three models, which are integrated to analyze certain factors that help in optimizing students' motivation for mathematical success. The proposed models will benefit students, educators, administrators of higher education, and societies around the world. A quantitative approach is used to design the research, which involved 366 female and 319 male students in different mathematics courses. The results show that the third, second, and first models are the top three in order. The third model accounts for 71.3% of the shift in the motivation for mathematical success. The difference in the motivation for mathematical success is explained by 66.3% in the second model and 65.0% in the first model.

Keywords: mathematical success, students' motivation, higher education, mathematical modeling, regression analysis

INTRODUCTION

Human beings use mathematics extensively in their daily lives, whether directly or indirectly through their occupations, businesses, and pursuits of endeavors. Han et al. (2015) indicate that mathematics is the core foundation and necessary tool to build and produce the skilled engineers and scientists of the future in fields of science, technology, engineering, and mathematics (STEM). Furthermore, Hammoudi (2020) emphasizes that mathematics is the significant and essential backbone to promote the creative and critical thinking of students in any major since mathematics will be demanded in almost all workplaces in the future. Therefore, the integration of mathematics with various disciplines cannot be overemphasized.

The optimization of the motivation of students in mathematics is an important facilitator in ensuring that they succeed in mathematics courses. The effect of different variables on predicting students' success in mathematics has been examined in several research studies. Lishchynska et al. (2023) emphasize that among several variables, students' motivation is the most significant predictor of their performance in first year service mathematics courses. Tran and Nguyen (2021) highlight the positive correlation between students' intrinsic motivation and their achievement in mathematics. It is reported by Boadu et al. (2023) that peer tutoring has a significant and positive impact on students' motivation in mathematics. Compared with placement test scores, Kushwaha (2014) reports several variables responsible for a good prediction of students' success and failure in mathematics. Among other social factors, Tolley et al. (2012) illuminate that socio-economic condition, parents' education, and parental involvement affect the performance of students in mathematics. It is emphasized by Kushwaha (2014) that among demographic information, gender of students is the most studied variable. Thus, various intrinsic, extrinsic, and demographic factors are associated with students' motivation for mathematical success.

According to Hammoudi (2019), there is a significant association between students' self-perceptions in mathematics and their motivation to succeed in the subject., i.e., students' motivation is related to the extent to which they perceive themselves to be able to acquire mathematical skills, abilities, reasoning abilities, excitement, and interest. Brezavšček et al. (2020) illustrate that improving students' mathematics

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Contribution to the literature

- This study adds to the body of literature on students' motivation for success in mathematics courses at universities by developing and integrating three mathematical models through novel graph-based visualization techniques.
- The study is developed based on a quantitative research approach and the findings show that the three models support in optimizing students' motivation for success in mathematics courses at higher education.

performance can be significantly impacted by boosting their mathematical confidence and lowering their mathematical anxiety. The findings of Soysal et al. (2022) indicate that the level of students' confidence is the main factor to predict their mathematics anxiety. There have been numerous studies revealing gaps in mathematics performance among students (Brezavšček et al., 2020; Dossi et al., 2021; Le et al., 2023; Lyons et al., 2022; Tolley et al., 2012), but few have investigated students' motivation for mathematical success. Therefore, this research study adds to the body of the relevant academic literature by producing and integrating three mathematical models, which are developed to optimize students' motivation for mathematical success.

After this introduction, there are numerous sections set up to explain the significance of the research, the literature review, the study methodology, the regression analysis and mathematical modeling, the comparative analysis, and the discussion of findings and recommendations. The study's limitations are highlighted in the paper's conclusion.

RESEARCH SIGNIFICANCE

This study contributes significantly to the literature from its endeavor to develop and integrate three mathematical models, which aim at optimizing students' motivation for mathematical success at universities. An incredible value is expected to be added to students and educators, administrators of universities, as well as societies from the created models.

The proposed models can be used by students in order to optimize their motivation for success in mathematics, which eventually allows them to successfully complete their mathematics courses and earn their desired degrees from their universities. From another perspective, the proposed models might be employed by colleges and universities to optimize students' motivation for mathematical success before they enroll in majors, which require completing courses of mathematics. The rates of students' failure and withdrawal in courses of mathematics are expected to be diminished through the three proposed models, which support the optimization of students' motivation for mathematical success. The proposed models can be used to identify students who have high levels of motivation for mathematical success and are more likely to successfully complete their courses of mathematics. In the same context, the proposed models may also be employed to detect students with low levels of motivation for success in mathematics and have high chances of failing the courses.

According to Vorderman et al. (2011), the civilization and culture of all societies will not be enhanced without the existence of mathematics. It is suggested by Niss (1994) that the growth and development of our societies is dependent on mathematics because of its endless integration with new areas, trends, and disciplines. For example, the development and spread of computers is considered as one of the most noteworthy accomplishments of mathematics on societies. The global health crisis brought about by the COVID-19 pandemic has led to an increased dependence on computers across several segments of society like economics, politics, family, religion, and education. The hardware and software of computers are designed, and function based on mathematics, and without it, modern societies would not be able to exist. This study aims at optimizing students' motivation for mathematical success and ultimately results in a positive impact on our societies.

LITERATURE REVIEW

There are significant theoretical and practical consequences for the academic self-concept of students in estimating their academic motivation and accomplishment, and this topic has attracted a lot of research (Kulakow, 2020; Marsh et al., 2005; Sewasew & Schroeder, 2019). According to several studies, the academic self-concept of students significantly correlates with a variety of performance and motivational factors, including interest (Gogol et al., 2016; Lohbeck et al., 2016; van der Westhuizen et al., 2023), students' engagement and effort (Guo et al., 2022; Schnitzler et al., 2021; Usán Supervía et al., 2020), persistence on tasks (Agtarap & Miranda, 2022; Anderson & Haney, 2021; Lee, 2022), aid-seeking behaviors and academic achievement (Hvizdak et al., 2019; Simonsmeier et al., 2020; Wu et al., 2021), course selection forms (Jónsdóttir & Blöndal, 2022; Nagy et al., 2006; Saß & Kampa, 2019), as well as internal and external motivators (El-Adl & Alkharusi, 2020; Marsh et al., 2005; Wang & Yu, 2023).

According to Huitt (2001), a learner is motivated when the learner is given the needed excitement to acquire and comprehend lessons. It is emphasized by

Brewer and Burgess (2005) that teaching and learning have come to recognize students' motivation as a crucial component. In order to increase the motivation of students to learn, lessen their anxiety, communicate desired goals and expectations, infuse them with enthusiasm, and help them with metacognitive awareness of goals, professionals in the field of education have an important and principal role in developing a suitable learning environment (Brophy, 2013; Tambunan, 2018).

The significant correlation between the self-efficacy of Swedish engineering students and their mathematics motivation is highlighted by Tossavainen et al. (2021). The study conducted by Corbiere et al. (2006) in France and Italy demonstrated a favorable correlation between self-perception, academic curiosity, and performance of school students in mathematics. According to House and Telese (2008), there is a direct link between Japanese and American school students' superior algebra performance and their good perceptions of their own mathematical prowess. In a study of students' academic performance at college-level mathematics in the USA, Gupta et al. (2006) found that older male students with positive attitudes toward mathematics and fewer absences from class were more likely to perform better in undergraduate mathematics at the beginning stage.

It is emphasized by Cheung and Slavin (2013) that technology can increase students' engagement and motivation for success in mathematics by piquing their interest in the subject and helping them gain more self-assurance when solving mathematical problems. Hammoudi and Grira (2023) demonstrate the strong impact of parents, siblings, friends, classmates, knowledgeable and skilled instructors, as well as online learning tools on students' perceptions of themselves in mathematics and their motivation for success in calculus courses. Morano et al. (2021) propose three research-supported strategies to boost the motivation and engagement of students in mathematics. It is proposed by Chao et al. (2016) that mathematics educators can use technology-based resources in a variety of ways, from using computer games to repurposing commercially accessible television shows in terms of difficulty and cost. As a result, instructors of mathematics can encourage students' interest in the subject by utilizing technology like electronic books with online resources such as MyLab Math, Blackboard, WileyPLUS, and other learning management systems. In addition to that, social media websites may be used as a powerful tool to improve the educational experience of students.

RESEARCH METHODOLOGY

Using a quantitative research methodology, a 55-item survey questionnaire is created to gather the dataset for this study. Students taking undergraduate mathematics courses are included in the study's sample. Numerous higher education institutes in the UAE were contacted in an effort to approach students. Four colleges and universities accepted the request to take part and gave the necessary ethical clearance for the study to be conducted on their students. The four institutions include one governmental academic institution of higher education and three private colleges and universities.

Using a straightforward random sampling process, students from the four colleges and universities were chosen, and they were asked to fill the survey form. Students in college algebra, college mathematics, trigonometry, calculus I, calculus II, linear algebra, differential equations, mathematics for business, mathematics for science and technology, engineering mathematics, and statistics for IT were given the survey. The study's sample is made up of 685 students. This sample is drawn from 800 distributed survey questionnaires; 319 male students and 366 female students make up this group. The students are given the option of responding to all 55 items on a 5-point Likert scale, with the possibilities ranging from strongly disagree (1) to strongly agree (5). The quantitative analysis was carried out using the SPSS 26.0 program. The demographic information of students is covered in the survey questionnaire for this study. The questionnaire's design is based on a number of theories of students' motivation and mathematics self-concept, including the self-determination theory (Deci & Ryan, 1985), the attribution theory (Weiner, 1985), and the mathematics self-concept theory (Shavelson et al., 1976) in order to measure students' assessments of their own skills, abilities, enjoyment, and perception of success in mathematics courses. Several validated instruments were utilized to tailor the questionnaire's items in additional to supplementary questions designed to the study's primary objective. The validated instruments include attitude toward mathematics inventory (ATMI), self-description questionnaire (SDQ), motivated strategies for learning questionnaire (MSLQ), and intrinsic motivation inventory (IMI).

According to Tapia and Marsh (2002), ATMI is made up of 40-item that gauge students' motivation, excitement, delight, confidence, and value in relation to mathematics. Several studies have shown the validity and dependability of ATMI, which is utilized in a number of nations (Ngurah & Lynch, 2013; Primi et al., 2020). According to Marsh and O'Neil (1984), SDQ mainly measured the 13 self-concept building blocks. SDQ, which has been used in several studies and proven to be accurate and trustworthy, measures both the academic and non-academic aspects of self-concept (Field et al., 2019; Ingles et al., 2012). Pintrich et al. were the ones who first developed MSLQ in 1991, which has 81 items. MSLQ looks at how college students feel about being motivated to learn about a certain subject and identifies the different learning techniques that students employ. MSLQ has a high level of validity and reliability, as shown by the outcomes of various research studies utilizing it (Ramírez Echeverry et al., 2016; Jackson, 2018). IMI, which is thought to be multidimensional and gauges participants' subjective responses to a particular assignment through intrinsic motivation and self-regulation, was built on the self-determination theory of Deci and Ryan (1985). Numerous studies' findings demonstrate the validity and reliability of IMI's items at levels that are acceptable (Leng et al., 2010; Ostrow & Heffernan, 2018).

FACTOR ANALYSIS

Fifty-five elements of the survey questionnaire were utilized to establish and generate the variables examined in the study. The link between the items is investigated in this study using a principal axis factor analysis with a Promax (oblique) rotation to determine how the items load into the factors. In earlier research studies, the majority of the items were demonstrated to be valid and reliable. For the purpose of determining if the factor analysis is acceptable for the dataset utilized in this study, Kaiser-Meyer-Olkin (KMO) values and p-values of Bartlett's test of sphericity have been computed. KMO value for the mathematics motivation items is 0.947, and the p-value for the Bartlett's test of sphericity is less than 0.001. Furthermore, KMO value for the mathematics self-perception items is 0.926, and the p-value for the Bartlett's test of sphericity is less than 0.001. KMO values of all the subscales are larger than 0.6, and the p-values of the Bartlett's test of sphericity are less than 0.001, so it is believed that the factor analysis is sufficient for the study's questions on mathematical motivation and mathematical self-perception. Cronbach's alpha reliability coefficients are calculated in order to ascertain the reliability coefficients of mathematical self-perceptions and mathematical motivation. The mathematics self-perception scale has a Cronbach's alpha reliability coefficient of (α=0.905), whereas that of the motivation of students for mathematical success is (α=0.939). It is found that Cronbach's alpha reliability coefficients are more than 0.80 across all scales, showing good internal validity and reliability.

REGRESSION ANALYSIS AND MATHEMATICAL MODELING

The purpose of this section is to describe how well the three models created for the study performed so that future research of a similar nature can be built on each model's basis. Thus, a variety of regression tests have been used to evaluate the effectiveness of each model. It is worthy to note that each of the three models designates students' motivation for mathematical success as the dependent variable. The next sections provide specific information on each of the three models, each of which has a different type and quantity of independent variables. The R^2 coefficient of determination, a measure of how well a regression line forecasts or approximates real values, is used to evaluate the accuracy of each model's prediction. The numerical value of R^2 gauges the percentage of the dependent variable's overall fluctuation that can be attributed to or explained through the variance in the independent variables. It accounts for the effect of the contribution from all independent variables (Xs) on the dependent variable (Y').

Furthermore, the behavior of the major variable, which measures students' motivation for mathematical success, has been examined through a global regression test to see how the independent variables (Xs) in each of the three constructed models explain its behavior. It is important to determine whether the major variable can be approximated through the use of other variables studied in each model. As a result, the test's objective is to determine if it's conceivable for all of the independent variables (Xs) to have zero regression coefficients (b=0). To put it another way, the test looks to see if the quantity of explained variations R^2 is a result of chance alone or if the independent variables have a role.

Model I

In the first model, it is looked at how a single independent variable, students' self-perceptions of themselves in mathematics, predicts the dependent variable, students' motivation for mathematical success. According to Weiner (1985), who used the attribution theory to describe this phenomenon, students' responses to academic achievements and failures, which include locus, stability, and controllability, determine their motivation to learn academic materials. It is determined by the locus whether a student's success or failure is due to factors that are inherent in the student, such as their talents or willingness, or external factors. The stability is a metric for gauging how consistently students attribute their achievements or disappointments in the long run. The term "controllability" refers to students' capacity to exercise self-restraint over their academically motivated efforts.

In light of this, it is possible to suggest that students' motivation for mathematical success may be linked to their perceptions of themselves in mathematics, which is formed from their attitudes and sentiments toward the subject. The performance of model I is used to test the following hypothesis, which attempts to predict students' motivation for mathematical success.

1. **Ho_1.** There is no relationship between students' self-perception of themselves in mathematics and their motivation for mathematical success (b_1=0).

Table 1, **Table 2**, and **Table 3** provide estimates for the suggested regression model, which determines the functional connection between students' motivation for mathematical success and their perceptions of their mathematical abilities.

Table 1. Model I summary

Model	R	R^2	Adjusted R^2	Standard error of estimate
1	.806[a]	.650	.649	11.15999

Note. [a]Predictors: (Constant) & self-perception in mathematics

Table 2. Model I ANOVA[a]

Model	Sum of squares	df	Mean square	F	Sig.
1 Regression	122,143.088	1	122,143.088	980.711	.000[b]
Residual	65,884.531	529	124.545		
Total	188,027.620	530			

Note. [a]Dependent variable: Students' motivation for mathematical success & [b]Predictors: (Constant) & self-perception in mathematics

Table 3. Model I coefficients[a]

Model	Unstandardized coefficients		Standardized coefficients	T	Sig.
	B	Standard error	Beta (β)		
1 (Constant)	29.291	2.699		10.851	.000
Self-perception in mathematics	1.181	.038	.806	31.316	.000

Note. [a]Dependent variable: Students' motivation for mathematical success

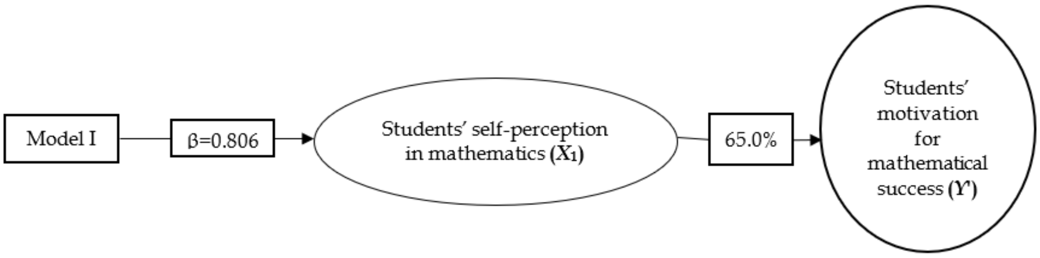

Figure 1. Graph-based visualization of model I (Source: Authors' own elaboration)

According to **Table 3**, students' motivation for mathematical success is positively and significantly predicted by their perception of their mathematical abilities (b=1.181, t=31.316, p<0.01).

Table 1 and **Table 2** demonstrate that students' perceptions of themselves as learners of mathematics account for 65% of the variation in their motivation (F[1, 529]=980.711, p<0.01, SE=11.15999). It is found that students' motivation for mathematical success and their perceptions of their mathematical abilities are closely associated, according to the multiple correlation coefficient (R=0.806). Based on the value of standard beta coefficient (standardized β=0.806), it is discovered that mathematics self-perception has a significant effect on students' motivation for mathematical success.

Figure 1 depicts a diagrammatic illustration of model I. As depicted in **Figure 1**, the substantial wholistic impact of mathematics self-perception alone with β=0.806 accounts for 65% of the improvement in students' motivation for mathematical success.

The first developed analytical model in **Figure 1** serves as the foundation for the mathematical expression that follows, which makes use of linear regression.

$$Y'=a+b_1X_1+u, \quad (1)$$

$$Y'=29.291+1.181X_1+u, \quad (1)$$

where Y' is dependent variable of students' motivation for mathematical success, X_1 is independent variable of self-perception of students in mathematics, a is intercept, b_1 is coefficient calculating how an independent variable affects a dependent variable, and u is assessment of the relevance of additional plausible explanatory variables due to stochastic error.

Model II

The second model is created to identify if there is a connection between students' motivation for mathematical success and the two aspects of their mathematics self-perception, i.e., their cognitive and affective self-perception. According to Schnitzler et al. (2021), some examples of the cognitive component of self-perception in mathematics include students' capacity to draw connections between the various branches of mathematics, identify their areas of strength and weakness, and use their abstraction processes. The students' internal worldview to achieve in mathematics, such as students' perceptions on how they grasp mathematics, students' assurance in their ability to study mathematics, and students' capacity to master and excel in mathematics, make up the affective element of self-perception in mathematics.

The second model examines the relationship between two independent factors, the students' affective and cognitive self-perception in mathematics, and the dependent variable, their motivation for mathematical success. As a result, it is also possible to hypothesize that

Table 4. Model II summary

Model	R	R^2	Adjusted R^2	Standard error of estimate
2	.814[a]	.663	.662	10.95752

Note. [a]Predictors: (Constant), cognitive self-perception in mathematics, & affective self-perception in mathematics

Table 5. Model II ANOVA[a]

Model	Sum of squares	df	Mean square	F	Sig.
2 Regression	124,632.091	2	62,316.045	519.009	.000[b]
Residual	63,395.529	528	120.067		
Total	188,027.620	530			

Note. [a]Dependent variable: Students' motivation for mathematical success & [b]Predictors: (Constant), cognitive self-perception in mathematics, & affective self-perception in mathematics

Table 6. Model II coefficients[a]

Model	Unstandardized coefficients		Standardized coefficients	T	Sig.
	B	Standard error	Beta (β)		
2 (Constant)	33.786	2.828		11.945	.000
Cognitive self-perception in mathematics	.881	.075	.456	11.686	.000
Affective self-perception in mathematics	2.049	.194	.411	10.546	.000

Note. [a]Dependent variable: Students' motivation for mathematical success

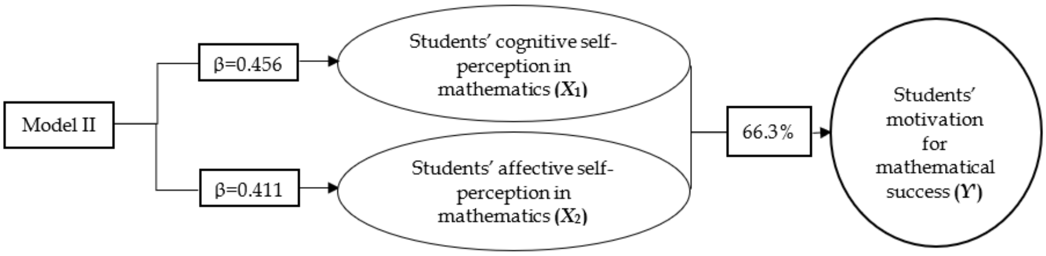

Figure 2. Graph-based visualization of model II (Source: Authors' own elaboration)

students' affective and cognitive self-perception in mathematics, as well as their motivation for success in mathematics courses, may be linked. For the purpose of forecasting students' motivation for mathematical success, the following two hypotheses have been created. Each of the two hypotheses is examined using model II's performance.

1. **Ho$_1$.** There is no relationship between students' cognitive self-perception of themselves in mathematics and their motivation for mathematical success (b_1=0).
2. **Ho$_2$.** There is no relationship between students' affective self-perception of themselves in mathematics and their motivation for mathematical success (b_2=0).

In **Table 4**, **Table 5**, and **Table 6**, the proposed regression model has been fitted to the research study's sample and demonstrates the relationship between students' cognitive and affective self-perceptions in mathematics and their motivation for mathematical success.

The results of **Table 6** show that both cognitive and affective aspects of mathematics self-perception positively and significantly predict students' motivation for mathematical success (cognitive self-perception in mathematics b=0.881, t=11.686, $p<0.01$; affective self-perception in mathematics b=2.049, t=10.546, $p<0.01$).

According to **Table 4** and **Table 5**, it is found that 66.3% of the shift in students' motivation for mathematical success is explained by both affective and cognitive aspects of their self-perceptions in mathematics ($F[2, 528]=519.009$, $p<0.01$, SE=10.95752). According to the multiple correlation coefficient (R=0.814), the two elements of students' mathematical self-perception are significantly connected with their motivation for mathematical success.

As indicated in **Figure 2**, the cognitive element of students' self-perception in mathematics (β=0.456) shows a greater influence on their motivation in comparison with the affective element (β=0.411), and combined elements account for 66.3% of the optimization in students' motivation for mathematical success.

Based on the second developed analytical model shown in **Figure 2**, which uses linear regression, the following mathematical statement is presented.

$$Y'=a+b_1X_1+b_2X_2+u, \quad (2)$$

$$Y'=33.786+0.881X_1+2.049X_2+u, \quad (2)$$

where Y' is dependent variable of students' motivation for mathematical success, X_1 is independent variable of cognitive self-perception of students in mathematics, X_2 is independent variable of affective self-perception of students in mathematics, a is intercept, b_1 and b_2 are

Table 7. Model III summary

Model	R	R^2	Adjusted R^2	Standard error of estimate
3	.845[a]	.713	.711	10.19060

Note. [a]Predictors: (Constant), cognitive self-perception in mathematics, affective self-perception in mathematics, aspirations of future employment and income, students' age, & amount of passed courses of mathematics

Table 8. Model III ANOVA[a]

Model	Sum of squares	df	Mean square	F	Sig.
3 Regression	133,340.001	5	26,668.000	256.798	.000[b]
Residual	53,585.732	516	103.848		
Total	186,925.734	521			

Note. [a]Dependent variable: Students' motivation for mathematical success & [b]Predictors: (Constant), cognitive self-perception in mathematics, affective self-perception in mathematics, aspirations of future employment and income, students' age, & amount of passed courses of mathematics

coefficients calculating how the independent variables affect a dependent variable, and u is assessment of the relevance of additional plausible explanatory variables due to stochastic error.

Model III

The first two generated models demonstrate a statistically significant association between students' motivation for mathematical success and the two components of mathematics self-perception. Ryan and Deci (2000) stress that the existence of intrinsic motivating variables alone, without considering extrinsic motivational factors, may not be sufficient, particularly if a given work is known to be not highly engaging or enjoyable. As a result, it is possible to postulate that students who learn mathematics are both intrinsically motivated by their enjoyment of the subject and extrinsically motivated by the possibility of lucrative employment prospects in the future. Furthermore, it is noted that the amount of mathematics courses completed by students and their age are important factors in pushing them for success in those courses (Abubakar et al. 2012; Gupta et al. 2006). The third model is a comprehensive model that regresses five independent variables on students' motivation for mathematical success as the dependent variable.

Hence, it can be postulated that factors such as students' cognitive and affective self-perception in mathematics, aspirations of employment and earning, age, and the amount of mathematics courses they have completed may all influence their motivation for mathematical success. The following five hypotheses have been developed to forecast students' motivation for mathematical success. The five hypotheses are examined in light of model III's performance.

1. **Ho_1.** There is no relationship between students' cognitive self-perception of themselves in mathematics and their motivation for mathematical success (b_1=0).
2. **Ho_2.** There is no relationship between students' affective self-perception of themselves in mathematics and their motivation for mathematical success (b_2=0).
3. **Ho_3.** There is no relationship between students' aspirations of future employment and their motivation for mathematical success (b_3=0).
4. **Ho_4.** There is no relationship between the amount of mathematics courses completed by students and their motivation for mathematical success (b_4=0).
5. **Ho_5.** There is no relationship between students' age and their motivation for mathematical success (b_5=0).

The estimates of the proposed regression model that identifies the relationship between students' motivation for mathematical success and their cognitive self-perception in mathematics, affective mathematics self-perceptions, aspirations for future employment and income, age of students, and the number of mathematics courses they have completed are presented in **Table 7**, **Table 8**, and **Table 9**.

Table 7, **Table 8**, and **Table 9** all use different goodness of fit metrics to analyze this comprehensive model, as seen above in **Table 9**. According to the coefficient of determination (R^2=0.713), which explains 71.3% of the change in students' motivation for mathematical success, the model offers a virtually extremely strong fit to the data. Only 0.2% of the model's variation is thought to be explained by chance, based on the adjusted coefficient of determination (adjusted $R^{2=}$0.711). Additionally, the high F-value (F[5, 516]=256.798, p<0.01, SE=10.19060) suggests a good fit to the data. According to the estimated multiple correlation coefficient (R=0.845), the dependent variable of students' motivation for mathematical success has a very high association with all of the other independent factors. The model's effects (bs) in **Table 9** have statistically significant t-values and p-values. **Table 9** demonstrates that the cognitive self-perception of students in mathematics (b=0.634, p<0.01), the affective self-perception of students in mathematics (b=1.851, p<0.01), and students' aspirations of future employment and

Table 9. Model III coefficients[a]

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Standard error	Beta (β)		
3	(Constant)	30.356	2.829		10.731	.000
	Cognitive self-perception in mathematics	.634	.077	.326	8.263	.000
	Affective self-perception in mathematics	1.851	.183	.371	10.121	.000
	Aspirations of future employment & income	1.446	.157	.271	9.230	.000
	Age of respondent	-.358	.419	-.021	-.856	.392
	Amount of passed courses of mathematics	.300	.325	.023	.921	.357

Note. [a]Dependent variable: Students' motivation for mathematical success

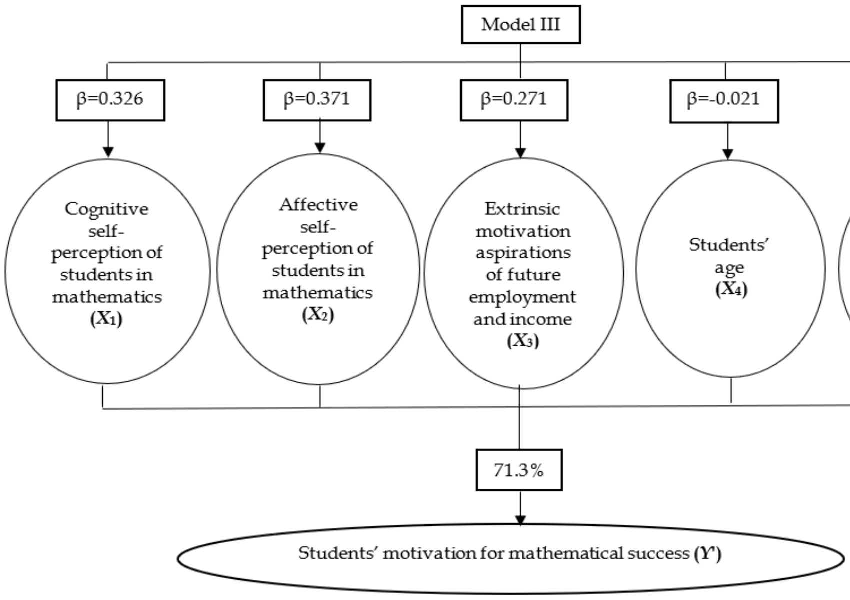

Figure 3. Graph-based visualization of model III (Source: Authors' own elaboration)

income (b=1.446, p<0.01) are the three most statistically significant predictors of students' motivation for mathematical success.

Model III is shown in a graph-based depiction in **Figure 3**. As shown in **Figure 3**, the affective self-perception in mathematics has the strongest predictive impact on students' motivation for mathematical success according to the value of standardized coefficient β=0.371. The second strongest predictor is the cognitive self-perception in mathematics with β=0.326, followed by students' aspirations of future employment and income with β=0.271, followed by the amount of completed courses of mathematics with β=0.023, and finally followed by the age with β=-0.021. The variation in students' motivation for mathematical success is explained by all five independent factors in 71.3%.

The third analytical model produced is shown in **Figure 3**. Using linear regression, the following mathematical statement is constructed:

$$Y'=a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+u, \quad (3)$$

$$Y'=30.356+0.634X_1+1.851X_2+1.446X_3-0.358X_4+0.300X_5+u, \quad (3)$$

where Y' is dependent variable of students' motivation for mathematical success, X_1 is independent variable of cognitive self-perception of students in mathematics, X_2 is independent variable of affective self-perception of students in mathematics, X_3 is independent variable of students' aspirations of future employment and income, X_4 is independent variable of students' age, X_5 is independent variable of the amount of mathematics courses completed by students, a is intercept, b_1 and b_5 are coefficients calculating how the independent variables affect a dependent variable, and u is assessment of the relevance of additional plausible explanatory variables due to stochastic error

COMPARATIVE ANALYSIS

This section aims at providing in a nutshell a comparative analysis for the responses provided by students based on gender. Four box-and-whisker plots are prepared to graphically compare between the responses of students in terms of their motivation for mathematical success, their self-perception in mathematics, their cognitive self-perception in mathematics, and their affective self-perception in mathematics. The findings are shown below in **Figure 4**, **Figure 5**, **Figure 6**, and **Figure 7**.

As shown in **Figure 4**, the motivation of students for success in mathematics has the highest level since the cumulative responses of all students range from around

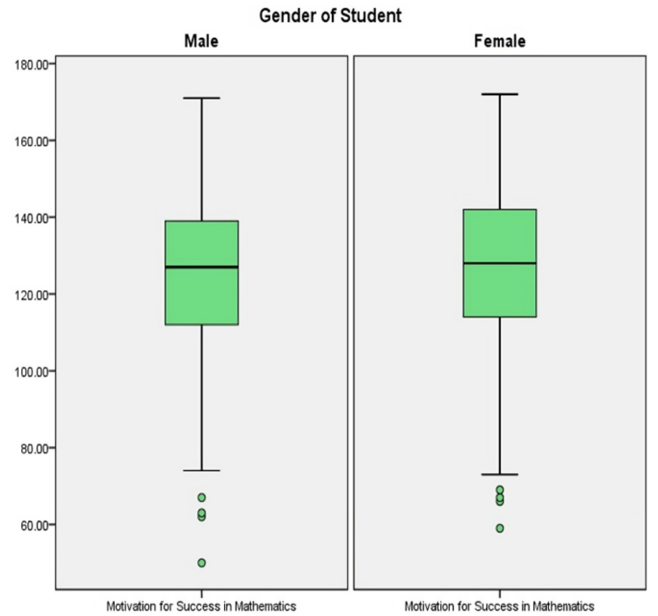

Figure 4. Comparative analysis-I (Source: Authors' own elaboration)

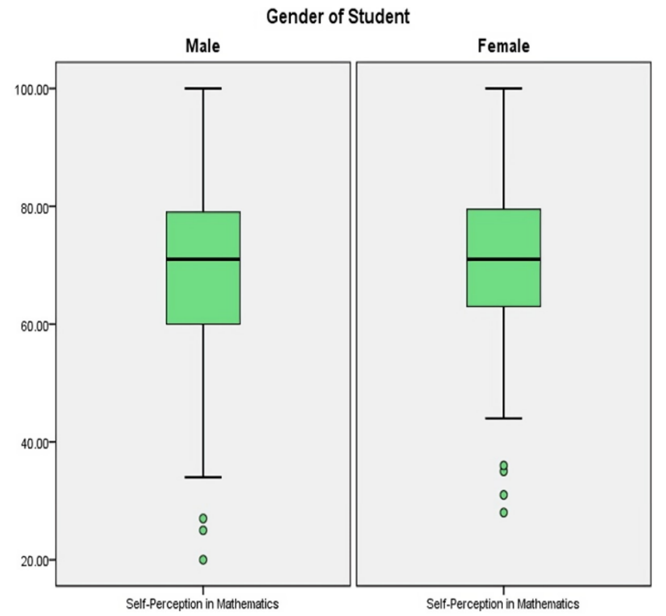

Figure 5. Comparative analysis-II (Source: Authors' own elaboration)

75 to 175. This range is calculated based on the responses provided by students for the items designed to measure their motivation for success in mathematics. The distributions of female and male students are very close to each other with four outliers in each gender. This indicates to the existence of few female and male students who have very low level of motivation for success in mathematics.

Figure 5 shows that the overall self-perception of students in mathematics is spread over a range from about 35 to 100 in terms of the cumulative responses of students. This range is quite high, but it is a smaller range in comparison with responses of students to their motivation for mathematical success. Based on the overall distributions of female and male students in **Figure 5**, it is important to note that self-perception of female students in mathematics spread over a smaller range around median in comparison with the responses of male students. This shows that most of female student have greater level of self-perception in mathematics than male students. Few outliers exist in both distributions, which suggest that few female and male students have very low level of self-perception in mathematics.

According to the findings in **Figure 6**, the cognitive self-perception of all students is high, with a range falling between 30 to 80 for the cumulative responses of students. **Figure 6** illustrates a reasonable resemblance in the responses of female and male students in terms of their cognitive self-perception in mathematics. Few extreme values exist in both distributions demonstrating that few female and male students have very low levels of cognitive self-perception in mathematics.

Figure 7 shows that distribution of female and male students looks identical in terms of their affective self-perception in mathematics. It is important to note that

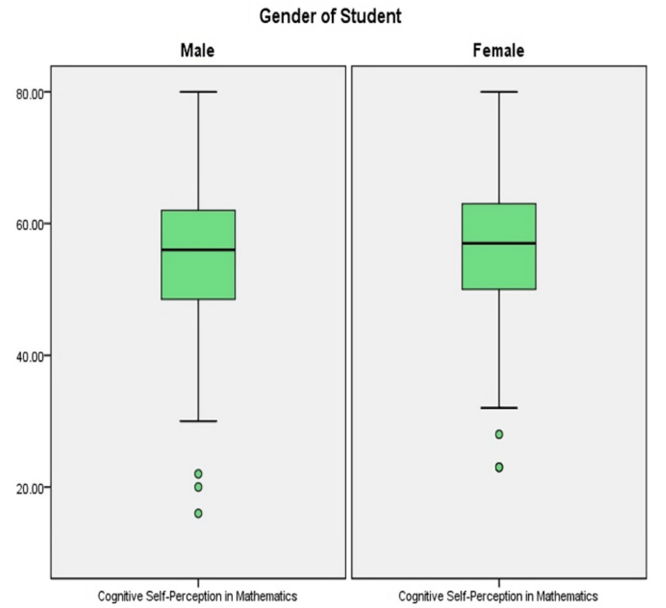

Figure 6. Comparative analysis-III (Source: Authors' own elaboration)

cumulative responses of students range from about six to 20 for their affective self-perception in mathematics. As shown in **Figure 7**, both distributions are skewed to left side, and there are two outliers amongst each gender. This indicates that both female and male students have low levels of affective self-perception in mathematics.

DISCUSSION

Three mathematical models are created as part of this research study, and they are anticipated to optimize students' motivation for mathematical success and make a valuable contribution to the literature. The most important finding of the study is the graph-based visualization that incorporates all three developed

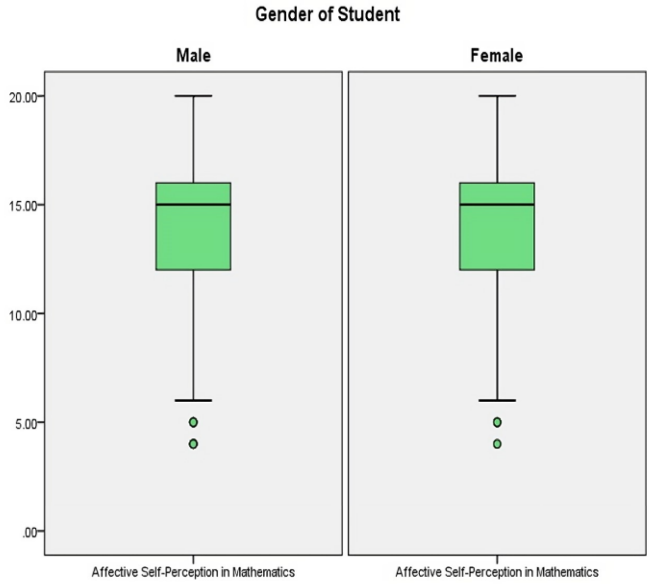

Figure 7. Comparative analysis-IV (Source: Authors' own elaboration)

models in **Figure 8**. The three integrated models in **Figure 8** show that model III is the strongest one followed by model II and model I in order. As indicated in **Figure 8**, the five independent variables all together account for 71.3% of the variation in students' motivation for mathematical success. **Figure 8** illustrates that model II and model I explain 66.3% and 65%, respectively of the change in students' motivation for mathematical success.

Figure 8 shows that the self-perception of students in mathematics accounts for 65.0% of the change in their motivation for mathematical success. It is reported in the literature that academic self-perception of students has significant correlation with their motivation (Berg & Coetzee, 2014). As shown in **Figure 4**, the distributions of responses provided by female and male students are very close in terms of their motivation. The results of Preckel et al. (2008) indicate that female students scored less than male students in measures of motivation. It is

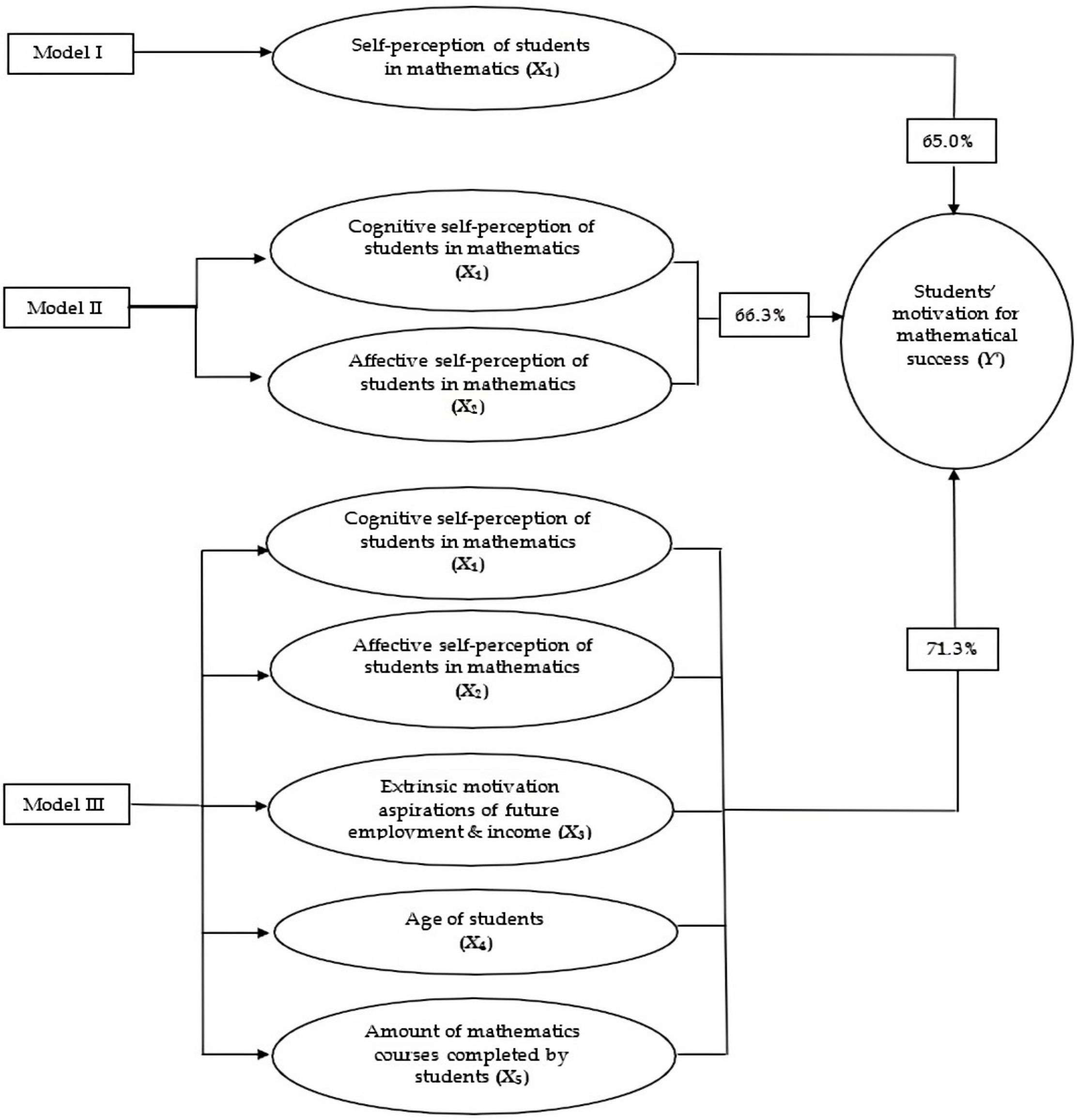

Figure 8. Graph-based visualization of three integrated models (Source: Authors' own elaboration)

significant to note that, based on the general distributions of male and female students in **Figure 5**, female students' responses to the questions about their self-perception of their mathematical abilities were distributed over a smaller range around the median than those of male students. The regression analysis findings of Rodriguez et al. (2020) reveals a significant gender difference in students' attitudes toward mathematics. Based on the distribution of responses of female and male students in **Figure 6** and **Figure 7**, it is noticed that there are few variations in their cognitive and affective self-perception in mathematics. This information matches with the results of Mejía-Rodríguez et al. (2021), which found that in most nations, there are considerable gender differences in students' self-perceptions in mathematics, with male student often performing better than female students.

CONCLUSIONS

The current study is being conducted in the UAE, which is a developing country with one of the best and fastest-growing higher education systems in the Gulf Cooperation Council as well as the surrounding area. The study contributes to the existing literature by producing three models that can be utilized by mathematicians, administrators, and institutions of higher education to optimize students' academic performance in mathematics courses and ultimately benefit societies and the globe. Based on the findings in each of the developed models, the affective and the cognitive self-perception of students in mathematics have the strongest impact on their motivation for mathematical success followed by the aspirations of students for future employment and income, and students' demographical information. To optimize students' performance in mathematics courses, instructors, mathematicians, and higher education institutions might use the following recommendations:

1. Enhancing students' affective self-perception in mathematics by motivating them to investigate novel mathematical ideas, work out novel mathematical issues, employ mathematical formulas to compute solutions, and solve challenging mathematical work.
2. Boosting the cognitive self-perception of students in mathematics by assessing their self-belief in their mathematical prowess, readiness to enroll in more courses of mathematics than the necessary ones, self-confidence to learn advanced mathematics, and preference for help when they need it.
3. Assessing students' career aspirations and taking students' demographic information into consideration.
4. Measuring the levels of students' motivation for mathematical success before they choose a college degree by utilizing the study's developed models and entering data about students' affective self-perception in mathematics, cognitive self-perception in mathematics, as well as aspirations of future employment and income.

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Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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