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Improving students' motivation in calculus courses at institutions of higher education: Evidence from graph-based visualization of two models

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Abstract

This research aims at improving students' motivation for success in calculus courses at higher education institutions by developing two models. The first model is developed to promote students' intrinsic motivation. The second model is integrated with the first model to improve students' intrinsic and extrinsic motivation. A mixed research methodology is used, which includes 153 students in calculus courses at three universities in the United Arab Emirates. The qualitative results of 15 interviews are divided into three themes including students' motivation for success in calculus, their mathematics self-concept, and other supporting elements. The regression analysis shows that 72.5% of the variation in students' intrinsic motivation for success in calculus is explained by five variables in model I and 98.5% of the variation in their intrinsic and extrinsic motivation is explained by three variables in model II. The findings of this study can be utilized by higher education institutions that offer calculus courses.

Keywords: intrinsic and extrinsic motivation, calculus courses, students' success, higher education

INTRODUCTION

Calculus is one of the most important courses taken by most students. It focuses on studying the rate of change of variables and how to develop modeling systems of such changes. In spite of the general perception that calculus does not have a significant use in life, calculus is applied and used directly in various disciplines such as economics, engineering, biology, science, and technology. Lovell (2004) clarifies that calculus supports economists to improve businesses since calculus can be used to identify the right time of buying and selling products, the number of expected buyers, and the profit margin of products and other associated costs and revenues. It is emphasized by Weinstock (1974) that calculus is used the most in the field of engineering, i.e., engineers and architects use calculus to find the exact size and shape of buildings, curves, roads, highways, tunnels, and bridges, which will not be safe as they are today without the existence of calculus. Neuhauser and Roper (2004) indicate that calculus is used in several applications by biologists and medical scientists, i.e., the growth rate of bacteria and modeling the population growth are applied in the medical fields through the use of calculus.

Although the direct use of calculus in various disciplines cannot be overemphasized, calculus is also used indirectly in life, e.g., the safety of vehicles is improved by using calculus and the payments of credit cards companies are performed through the use of calculus.

The success of students in calculus courses can be improved by enhancing students' intrinsic and extrinsic motivation in calculus courses (Matthews et al., 2013). Numerous studies investigated the impact of different variables on the success of students in calculus courses (Hurdle, 2022; Rickard & Mills, 2018). It is emphasized by Minichiello and Hailey (2013) that calculus courses are the gateway courses for students in engineering programs and students' success in calculus is a reliable predictor of students' persistence on engineering majors. According to Koch and Herrin (2006), there is a statistically significant association between students' performance in calculus and their final graduation achievement in engineering majors. It is reported by Hagman et al. (2017) that students' chances of learning calculus in science, technology, engineering, and mathematics (STEM) majors are negatively correlated with variables like gender, lack of prior calculus knowledge, and lack of student-centered learning.

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Contribution to the literature

- The study contributes to the current literature about students' motivation for success in calculus courses at higher education by developing and integrating two mathematical models through novel graph-based visualization techniques.
- The study is developed based on a mixed research methodology using an explanatory approach in which the qualitative analysis is conducted to complement and expand on the quantitative findings.
- The findings show that the intrinsic motivation and global motivation of students for success in calculus courses are predicted by several variables in model I and model II which are supported by three themes including students' motivation for success in calculus, their mathematics self-concept, and other supporting elements.

It is emphasized by Stanberry (2018) that the increased learning can be produced in the classroom of calculus courses through the strategic engagement of students in calculus courses. It is recommended by Hammoudi (2020) to enhance the confidence of students in learning advanced courses of mathematics and engage them by solving real life application problems. Rasmussen and Ellis (2013) report several variables that contribute to forcing students to switch from STEM majors and avoid taking calculus II. These variables include the negative experience encountered in calculus I, the necessity to allocate more time and energy than students' capacity, the lack of good understanding in calculus I, and the poor performance and bad grade obtained in calculus I. Although several research studies attempted to examine the predictive factors of students' success in calculus courses (Hagman et al., 2017; Koch & Herrin, 2006; Stanberry, 2018; Rasmussen & Ellis, 2013); few studies provided sufficient attention to students' intrinsic and extrinsic motivation in calculus courses. Therefore, this research study bridges the gap between students' intrinsic motivation and students' extrinsic motivation in calculus courses by generating two mathematical models, which are integrated through the use of a novel graph-based visualization to improve students' global motivation including intrinsic and extrinsic motivation for success in courses of calculus.

LITERATURE REVIEW

The predictive factors of students' success in calculus courses have significant implications in practice as well as theory and several studies have shed the light on different factors (Hagman et al., 2017; Koch & Herrin, 2006; Stanberry, 2018; Rasmussen & Ellis, 2013). Students enrolled in calculus I were studied by Pyzdrowski et al. (2013) in the USA. It is emphasized by Pyzdrowski et al. (2013) that the successful completion of calculus courses is strongly correlated with students' attitudes toward calculus courses, which are not only influenced by the previous experience and preparation of students, but also by the primary psychosocial variables. Ubuz (2011) conducted written exams on integrals, sequences, and series with students before and after completing calculus II course. The study was held at the Middle East Technical University in Turkey, and the results indicate that variables such as gender and prior achievements of students are related to students' success in calculus II courses.

It is highlighted that the intrinsic motivation of students for success in calculus is impacted by various dispositional and achievement variables such as students' attitudes toward mathematics (Pyzdrowski et al., 2013), students' beliefs about mathematics (Rasmussen & Ellis, 2013), students' academic engagement (Stanberry, 2018) and students' extrinsic motivation (Hagman et al., 2017) The findings of Hammoudi (2019) show that several intrinsic, extrinsic, and demographic factors contribute in predicting students' motivation for success in courses of mathematics. The beliefs of students in courses of calculus are not only inclusive of students' mathematical knowledge, but they can also refer to specific conceptions, i.e., the required procedures of finding limits, the necessary steps of calculating derivatives, and the needed series of actions to find integrals. It is emphasized by Froiland and Davison (2016) that the enrollment of students in higher-level mathematics courses like trigonometry and calculus is predicted through the intrinsic motivation of students and their parents' expectations.

Numerous research studies have shed the light on mathematics self-concept of students and its considerable theoretical and practical implications to anticipate the achievements of students in mathematics courses. The level of students' participation in mathematics is predicted by the intrinsic worth and self-perceptions of students, according to Watt et al. (2006), who discovered that interest in and like of mathematics have a substantial impact on Australian students' selections of mathematics courses. It is highlighted by Afgani et al. (2019) that there is an important link between Indonesian students' procedural knowledge and their perceptions about themselves in mathematics. The self-concept and achievements of students in mathematics were examined by Han (2019) and it is indicated that gender influences significantly students' self-perceptions and achievement scores, i.e., the ratings of mathematics competence and scores in a test of mathematics of male students were high compared to female students. It is highlighted by Park et al. (2021) that mathematics misalignment of students' academic standards diminishes students' interest in perusing STEM courses. It is reported by Hine (2019) that students in western Australia avoid enrolling in high level courses of mathematics and one of the main reasons of this avoidance behavior is the dissatisfaction of students with mathematics due to short-term goals and attitudes towards mathematics. It is highlighted by Sikora and Pitt (2019) that gender significantly predicts students' selections of levels of mathematics study in the Australian tertiary admission rank. It is emphasized by Watt et al. (2006) that male students liked mathematics more than female students. The relevance of mathematics courses including calculus at Queensland University was analyzed by Easey and Gleeson (2016) from leaders' perspective and teachers' perspective. The findings of Easey and Gleeson (2016) indicate that lack of students' development of future aspirations restricts the opportunity to study senior calculus courses, which limits students' future potentials. The beliefs of students about mathematics in calculus courses are explored by Ayebo and Mrutu (2019) and it has been found that factors like effort, practicality, difficult problems, understanding, and steps are the major predictors of students' beliefs about mathematics in calculus courses.

Hence, the gap between students' intrinsic motivation and students' extrinsic motivation for success in calculus courses is bridged in this research study. In model I, the effects of five factors are investigated in relation to students' intrinsic motivation for success in calculus courses. Then, the impact of three variables is analyzed on the global motivation of students for success in calculus courses in model II. Finally, both models are integrated using a graph-based visualization to improve the intrinsic and extrinsic motivation of students in the United Arab Emirates (UAE).

METHODOLOGY

The study is developed based on a mixed research methodology using an explanatory approach in which the qualitative analysis is conducted to complement and expand on the quantitative findings. The quantitative part of the research methodology is conducted by designing a questionnaire to collect data from the primary sources of information. One the other side, a descriptive approach is utilized in the qualitative part of the research methodology. For this purpose, several universities in the UAE were approached to target students in calculus courses. Three universities that offer courses of calculus in STEM programs granted the ethical approvals and accepted to take part in the study. From the three universities, one institution is considered as the oldest governmental institution of higher education in the UAE and the other two institutions are private institutions of higher education.

Participants

Students taking calculus I and calculus II courses are the participants in this study. To select students from the three academic institutions of higher education, a simple random sampling technique is used, and students were requested to complete the survey questionnaire designed for the research. All calculus students registered in three universities in the UAE made up the study's population. The sample targeted students registered in calculus courses and the final sample included the responses of 153 students out of 165 disseminated questionnaires, which resulted in 92.7% as a response rate. The sample size is 153, which consists of 85 male students and 68 female students. The sample size of the research study is calculated using a confidence level of 95%, a margin of error of 8%, and a standard deviation of 0.5. The chosen confidence level tells that there is a 95% probability that when a sample is selected multiple times, the true population parameter will be contained in the confidence interval. From all students included in the sample, 101 students were registered in calculus I courses, and 52 students were registered in calculus II courses. The semi-structured interviews were conducted with a total of 15 students in order to collect the qualitative data to support and expand on the quantitative findings.

Questionnaire Design

The survey questionnaire of this study is designed by including questions on students' demographic information. A total of 55 items are developed to gather the quantitative information. The design of the questionnaire is grounded on several 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' evaluations of their own skills, abilities, delight, and perception of success in calculus courses. The items of the developed questionnaire are incorporated from certain validated instruments including the motivated strategies for learning questionnaire (MSLQ), intrinsic motivation inventory (IMI), attitude toward mathematics inventory (ATMI), self-description questionnaire (SDQ), and supplementary questions, which were tailored to achieve the main objective of the study.

The MSLQ is an 81-item, self-report questionnaire that was initially designed by Pintrich et al. (1991). The objective of the MSLQ is to measure the orientations of college students' motivation in a specific subject and identify the diverse learning strategies of students. According to Pintrich et al. (1991), the MSLQ's development is fundamentally based on the social cognitive perspective of motivation and self-regulated learning. The MSLQ has been used in several research investigations, and the findings show that the instrument has a good level of validity and reliability (Liu & Lin, 2010; Pintrich et al., 1993). The IMI was built on the principles of Deci and Ryan's (1985) self-determination theory. The IMI distinguishes itself by being multidimensional and by using intrinsic motivation and self-regulation to gauge participants' subjective reactions to a given assignment. The results of numerous studies show that the IMI's items are valid and reliable according to acceptable levels (Deci & Ryan, 1985; Monteiro et al., 2015). The ATMI is a 40-item test with psychometric features that measures four aspects of students' attitudes toward mathematics, including motivation, enthusiasm, delight, confidence, and value (Tapia & Marsh, 2002). The ATMI has been used in several countries, and multiple investigations have established its validity and reliability (Lim & Chapman, 2013; Zakariya, 2017). The 13 components of self-concept were predominantly measured by the SDQ (Marsh & O' Neil, 1984). Both academic aspect and non-academic aspect of self-concept are measured by the SDQ, which was used in various investigations proofed to be valid and reliable (Erdogan & Sengul, 2014; Leach et al., 2006).

The questionnaire designed in this study has the same psychometric features of other questionnaires employed in previous research studies. The questionnaire includes 10 items designed to measure the significance and need for calculus courses, 10 items to measure students' perception of calculus success, and 11 items to measure students' delight of calculus courses. A total of 31 items are used to measure the intrinsic motivation of students for success in calculus courses. Furthermore, the questionnaire includes four items to measure students' projected careers and earnings in the future, 16 items to assess the cognitive aspect of mathematics self-concept in calculus, and four items to quantify the affective aspect of mathematics self-concept in calculus. The analogy and cohesiveness between all the items of the questionnaire are measured through the use of a reliability test. The purpose of this test is to identify how each subscale is reliable by measuring the homogeneity and cohesiveness between the items within each subscale and generating an alpha value that represents how the items of each subscale are homogeneous and cohesive. The higher the value of alpha for a particular subscale indicates that this specific subscale is more reliable. Therefore, the Cronbach's alpha reliability coefficients are calculated for all items within specific subscales. The findings indicate an alpha value above 0.830 ($\alpha > 0.830$) for all items within specific subscales. The findings prove high level of reliability and validity for all the items of the questionnaire indicating that the internal consistencies for the scores of items are adequate. All 55 items on the questionnaire have options ranging from strongly disagree (1) to strongly agree (5) on a 5-point Likert scale. The quantitative analyses of the collected data are performed through the use of the software of SPSS 26.0.

Model I

The first model examines how five independent variables, including the age of students, the projected careers and earnings of students, the quantity of mathematics courses finished by students, and the cognitive as well as the affective components of students' mathematics self-concept in calculus courses, can predict their intrinsic motivation for success in calculus courses as the dependent variable.

The attribution theory of Weiner (1985) focuses not only on the reasons and attributions given by students for successes or failures in a specific task, but it also focuses on the factors that impact such attributions as well as how students' behaviors are influenced by such attributions. The reactions of students to academic successes and failures are the key determinants of the motivation of students to learn academic subjects (Weiner, 1985). The first independent variable included in this mathematical model is cognitive mathematics self-concept in calculus courses. The cognitive part of mathematics self-concept in calculus courses is measured by the realization of students of their own mathematical knowledge in calculus courses (Tanner & Jones, 2000). Examples of the cognitive components of mathematics self-concept in calculus courses include the ability of students to develop relationships between the various topics such as differentiation and integration, identify their strengths and weaknesses, and utilize their abstraction processes such as the fundamental theorems of calculus. The second independent variable examined in model I is the affective component of mathematics self-concept in calculus courses. Tanner and Jones (2000) clarify that affective mathematics self-concept in calculus courses is represented by the developed belief system of students for success in calculus courses such as the beliefs of students about the nature of their understanding of continuity and the sandwich theorem, the self-confidence of students in learning calculus, and the ability of students to successfully complete calculus courses. The projected careers and earnings of students in the future is considered the third independent variable studied in this mathematical model. The intrinsic motivation by itself might be insufficient without considering the extrinsic motivation provided that a certain task is thought to not be particularly engaging or delightful (Ryan & Deci, 2000). The independent variable of the projected careers and earnings of students in the future is used to measure students' extrinsic motivation in calculus courses. The fourth and fifth variables studied in model I are the age of students and the quantity of mathematics courses finished by students. Hoffman et al. (2009) underline that the age of students had a significant influence on their success in mathematics courses. The results of Sonnert and Sadler (2014) suggest that the beneficial role of college pre-calculus courses is to assist students who might give up on mathematics or STEM majors in the face of calculus courses.

To forecast the intrinsic motivation of students for success in calculus courses, the following five hypotheses are proposed. The five hypotheses are examined based on the performance of model I.

1. **Ho_1:** Cognitive mathematics self-concept in calculus courses has no relationship with the intrinsic motivation of students for success in calculus courses (b_1=0).
2. **Ho_2:** Affective mathematics self-concept in calculus courses has no relationship with the intrinsic motivation of students for success in calculus courses (b_2=0).
3. **Ho_3:** The projected careers and earnings of students in the future has no relationship with the intrinsic motivation of students for success in calculus courses (b_3=0).
4. **Ho_4:** The age of students has no relationship with the intrinsic motivation of students for success in calculus courses (b_4=0).
5. **Ho_5:** The quantity of mathematics courses finished by students has no relationship with the intrinsic motivation of students for success in calculus courses (b_5=0).

Model II

In the second model, the global motivation including intrinsic and extrinsic motivation of students for success in calculus courses is assigned as the dependent variable. Model II examines how the global motivation of students for success in calculus can be predicted by three independent variables of intrinsic motivation that are generated from model I. The three independent variables include the significance and need for calculus, students' perception of calculus success, and students' delight of calculus.

The first independent variable included in this mathematical model is the significance and need for calculus courses. The self-determination theory emphasizes that the behaviors of students' engagement in course materials to achieve feelings of importance, ability, and self-determination are considered to be intrinsically motivated behaviors (Deci & Ryan, 1985). For example, presenting the importance of calculus in real life situations enhances students' success, i.e., the first derivative of a chemical particle's location with respect to time can be used to determine its velocity, while the second derivative of a vehicle's position with respect to time can be used to determine its acceleration. The second independent variable examined in model II is the perception of success in calculus courses. The effort and work allocated by students on an academic task outside the requirements of the task prove that students are intrinsically motivated to accomplish due to the perceived experience and satisfaction from this accomplishment (Bong & Skaalvik, 2003). The intrinsic motivation to engage in an academic task stems from the experience and perceived success in this particular task (Ryan & Deci, 2000). Students' delight of calculus courses is assigned as the third independent variable examined in this mathematical model. The level of students' intrinsic motivation to experience the stimulations in the learning process increases whenever students start to attend their lectures to reach the pleasure of provoking discussions in the class or when a calculus textbook is read by students to achieve the strong feelings of the cognitive enjoyment as a result of the passionate and excitable theories and applications within the textbook.

The following three hypotheses have been articulated to predict the global motivation of students for success in calculus courses. The performance of model II is utilized to examine the three hypotheses.

1. **Ho_1:** The significance and need for calculus courses has no relationship with the global motivation of students for success in calculus courses (b_1=0).
2. **Ho_2:** Students' perception of calculus success has no relationship with the global motivation of students for success in calculus courses (b_2=0).
3. **Ho_3:** Students' delight of calculus courses has no relationship with the global motivation of students for success in calculus courses (b_3=0).

QUANTITATIVE RESULTS

The discussion in this section is about the performance of the two mathematical models generated in this study. The calculated performance of each of the two models is utilized in confirming the significance of each model as a primary substance for a similar research in the future. For this purpose, several statistical regression analyses have been applied to examine the performance of each model.

Model I Results

Table 1, **Table 2**, and **Table 3** provide estimates for the suggested regression model for the sample of this study, which identifies the functional link between students' intrinsic motivation for success in calculus courses and five independent variables.

As shown in **Table 1**, **Table 2**, and **Table 3**, this comprehensive model has been examined through several goodness of fit indicators. According to the coefficient of determination for model I (R^2=0.725), which accounts for 72.5% of the variation in students'

Table 1. Model I summary

Model	R	R square	Adjusted R square	Standard error of the estimate
1	.852[a]	.725	.714	10.49632

Note. [a]Predictors: (Constant), cognitive aspect of mathematics self-concept in calculus, affective aspect of mathematics self-concept in calculus, projected careers & earnings in the future, age of respondent, & quantity of finished courses of mathematics

Table 2. Model I ANOVA[a]

Model		Sum of squares	df	Mean square	F	Significance
1	Regression	34,924.775	5	6,984.955	63.400	.000[b]
	Residual	13,220.725	119	110.173		
	Total	48,145.500	125			

Note. [a]Dependent variable: Intrinsic motivation of students for success in calculus courses & [b]Predictors: (Constant), cognitive aspect of mathematics self-concept in calculus, affective aspect of mathematics self-concept in calculus, projected careers & earnings in the future, age of respondent, & quantity of finished courses of mathematics

Table 3. Model I coefficients[a]

Model		UC		SC	T	S
		B	SE	β		
1	(Constant)	22.186	6.480		3.424	.001
	Cognitive aspect of mathematics self-concept in calculus	.848	.161	.407	5.273	.000
	Affective aspect of mathematics self-concept in calculus	2.101	.375	.393	5.610	.000
	Projected careers and earnings in the future	.932	.340	.165	2.739	.007
	Age of respondent	-.251	.822	-.015	-.305	.761
	Quantity of finished courses of mathematics	.588	.790	.037	.744	.458

Note. [a]Dependent variable: Intrinsic motivation of students for success in calculus courses; UC: Unstandardized coefficients; SC: Standardized coefficients; S: Significance; & SE: Standard error

intrinsic motivation for success in calculus courses, the data fit to the model is quite strong.

Table 1 shows that according to the adjusted coefficient of determination (adjusted R^2=0.714), only 1.1% of the variation of model I can be attributed to chance. As displayed in **Table 1** and **Table 2**, an excellent fit to the data is indicated by a high numerical F-value ($F[5, 119]=63.400$, $p<0.01$, SE=10.49632). As shown in **Table 1**, the computed multiple correlation coefficient (R=0.852) shows that there is a very significant link between all of the independent variables and the dependent variable, which is students' intrinsic motivation for success in calculus classes.

Furthermore, as shown by the t-values and p-values in **Table 3**, the majority of the model effects (bs) are statistically significant. The model indicates that the cognitive aspect of mathematics self-concept in calculus (b=0.848, $p<0.01$), the affective aspect of mathematics self-concept in calculus (b=2.101, $p<0.01$), and the projected careers and earnings of students in the future (b=0.932, $p<0.01$) are considered to be the most significant predictors of the intrinsic motivation of students for success in calculus. Since all models' effects (bs) are not equal to zero, the five null hypotheses in model I can be refuted, and the alternative hypotheses can be accepted proving that a relationship exists between the intrinsic motivation of students for success in calculus courses and other five independent variables.

The graph-based visualization of model I is presented in **Figure 1**.

Based on the values of the standardized coefficients, it is shown in **Figure 1** that, with β=0.407, the cognitive aspect of mathematics self-concept has the highest predictive effect on students' intrinsic motivation for success in calculus courses. The affective aspect of mathematics self-concept in calculus courses is the second strongest variable with β=0.393, followed by the projected careers and earnings in the future with β=0.165, followed by the quantity of mathematics courses finished by students with β=0.037, and finally followed by the age of students with β=-0.015. Notably, all five independent factors account for 72.5% of the change in students' intrinsic motivation for success in calculus courses.

The following mathematical equation of model I using linear regression is based on the first generated analytical model in **Figure 1**.

$$Y' = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + u \quad (1)$$

$$Y' = 22.186 + 0.848X_1 + 2.101X_2 + 0.932X_3 - 0.251X_4 + 0.588X_5 + u,$$

where Y' is model I dependent variable, X_1 to X_5 are model I five inputted independent variables, a is intercept, b_1 to b_5 are coefficients assessing how the dependent variable is impacted by the independent variables, and u is stochastic error assessing the significance of additional probable explanatory variables

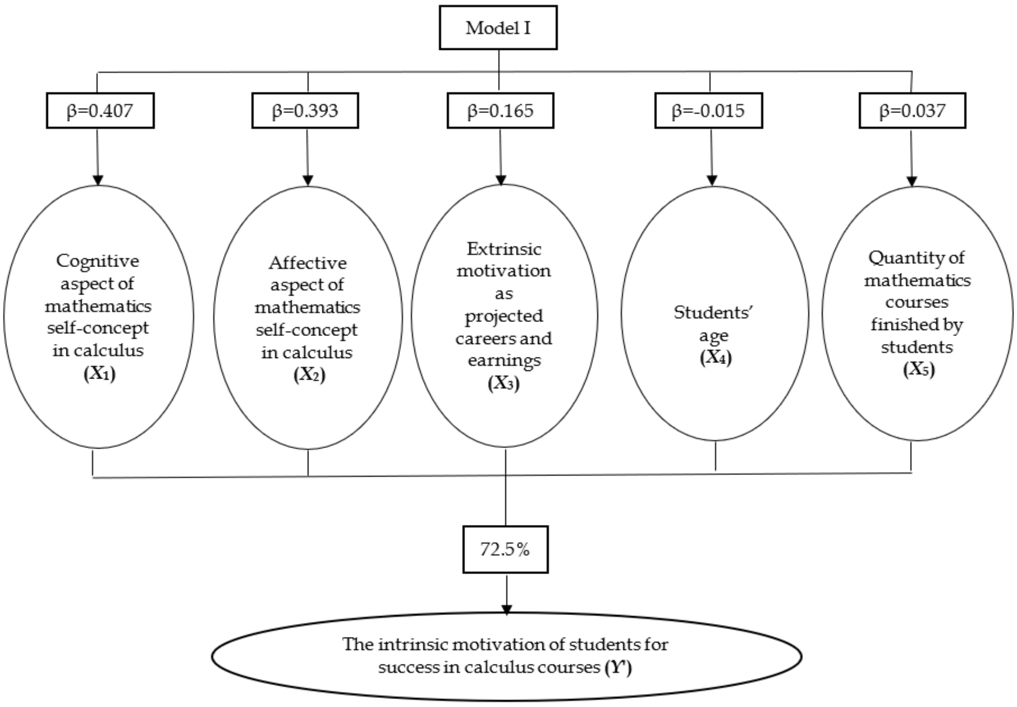

Figure 1. Graph-based visualization of model I (Source: Authors' own elaboration)

Table 4. Model II summary

Model	R	R square	Adjusted R square	Standard error of the estimate
2	.993[a]	.985	.985	2.76929

Note. [a]Predictors: (Constant), significance & need for calculus courses, students' perception of calculus success, & students' delight of calculus courses

Table 5. Model II ANOVA[a]

Model		Sum of squares	df	Mean square	F	Significance
2	Regression	66,116.778	3	22,038.926	2,873.780	.000[b]
	Residual	989.297	129	7.669		
	Total	67,106.075	132			

Note. [a]Dependent variable: Students' global motivation of intrinsic and extrinsic motivation & [b]Predictors: (Constant), significance & need for calculus courses, students' perception of calculus success, & students' delight of calculus courses

Table 6. Model II coefficients[a]

Model		UC		SC	T	S
		B	SE	β		
2	(Constant)	3.258	1.588		2.051	.042
	Significance and need for calculus courses	1.079	.058	.348	18.447	.000
	Students' perception of calculus success	1.008	.059	.271	16.988	.000
	Students' delight of calculus courses	1.195	.040	.488	30.166	.000

Note. [a]Dependent variable: Students' global motivation of intrinsic and extrinsic motivation; UC: Unstandardized coefficients; SC: Standardized coefficients; S: Significance; & SE: Standard error

Model II Results

The functional relationship between the global motivation of students for success in calculus courses and three independent variables is estimated for the proposed regression model in the following.

Table 4 and **Table 5** show that the significance and need for calculus courses, students' perception of calculus success, and students' delight of calculus courses account for 98.5% of the change in the global motivation of students for success in calculus courses ($F[3, 129]=2873.8$, $p<0.01$, $SE=2.76929$). As shown in **Table 4**, the multiple correlation coefficient ($R=0.993$) indicates that the significance and need for calculus courses, students' perception of calculus success, and students' delight of calculus courses are strongly correlated with the global motivation of students for success in calculus courses.

Table 6 illustrates that students' delight of calculus courses is a very significant estimator of the global

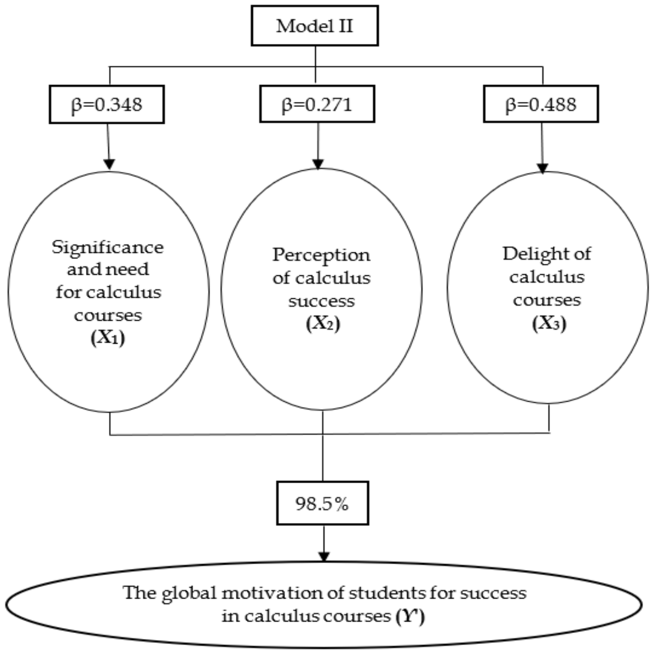

Figure 2. Graph-based visualization of model II (Source: Authors' own elaboration)

motivation of students for success in calculus courses (b=1.195, t=30.166, p<0.01), the significance and need for calculus courses is the second significant estimator of the global motivation of students for success in calculus courses (b=1.079, t=18.447, p<0.01) and students' perception of calculus success is the third significant estimator of the global motivation of students for success in calculus courses (b=1.008, t=16.988, p<0.01). Since the b value of the three independent variables is not equivalent to zero, the three articulated null hypotheses might be refuted, and the alternative hypotheses can be accepted. Therefore, it is possible to assume that there is an existing and strong relationship between the global motivation of students for success in calculus courses and the significance and need for calculus courses, students' perception of calculus success, and students' delight of calculus courses. **Figure 2** provides the graphical summary of model II.

As indicated in **Figure 2**, the graph-based visualization of model II shows that students' delight of calculus courses with β=0.488 has the strongest impact on their global motivation for success in calculus courses, followed by the significance and need for calculus courses with β=0.348, and finally followed by students' perception of their calculus success with β=0.271. It is evident that all the three variables together explain 98.5% of the change in student's success in calculus courses.

The mathematical expression of model II using linear regression is given below and is based on the second analytical model produced in **Figure 2**.

$$Y' = a + b_1X_1 + b_2X_2 + b_3X_3 + u \quad (2)$$

$$Y' = 3.258 + 1.079\,X_1 + 1.008X_2 + 1.195X_3 + u,$$

where Y' is model II dependent variable, X_1 to X_3 are model II three inputted independent variables, a is intercept, b_1 to b_3 are coefficients assessing how the dependent variable is impacted by the independent variables, and u is stochastic error assessing the significance of additional probable explanatory variables

QUALITATIVE RESULTS

This section seeks to analyze the qualitative information gleaned from interviews with the intention of connecting the analysis to the study's quantitative findings. The qualitative information derived from extensive semi-structured interviews aids in elucidating the phenomena of intrinsic motivation and global motivation of students for success in calculus courses. A total of 15 students in courses of calculus accepted to participate in the interviews and the participants' answers were recoded and afterwards transcribed. Each response was transcribed many times to guarantee the veracity and authenticity of the answers. The responses of all interviewees were coded and divided into three themes that correspond to the intrinsic and extrinsic motivation of students for success in calculus courses, the mathematics self-concept of students in calculus courses, and other supportive elements.

Theme I

The intrinsic and extrinsic motivation of students for success in calculus courses include multiple aspects like the significance and need for calculus courses, students' perception of calculus success, students' delight of calculus courses, and the projected careers and earnings of students in the future. During the interviews, the respondents used a number of idioms and concepts that amply demonstrated the significance and need for calculus courses. The idioms and concepts are summarized in the following:

> It is important for the engineering courses, and we need to know the basic mathematics to use it in our life. I am an electrical engineer so calculus courses are important for my career; I think mathematics is important because it teaches you something that may need in life; it is important because we use calculus in our life like 3D drawing; university calculus is only important for university study and future work. It allows for a better understanding of many concepts in other courses like physics and artificial intelligence, etc. At the professional level, having strong understanding of calculus concepts is important because nobody knows where they will work, and different professions require different mathematics; calculus courses are one of the most important courses on my future profession. Mathematics and physics are fundamental to the field of civil engineering.

The aforementioned idioms and concepts indicate that the significance and need for calculus courses influences the motivation of students for success in calculus courses. The students' responses demonstrate their understanding of the important and crucial role that mathematics has in the academic, personal, and professional domains. This understanding is what ultimately motivates students to prepare for and do well in calculus courses. Additionally, it has been mentioned that calculus courses have strong connections to a number of fields, including engineering, sciences, physics, artificial intelligence, and daily activities.

Throughout the interviews, the respondents expressed their perceptions of calculus success using a number of words and phrases:

> Practice is a very useful approach that motivates my success in calculus courses, because if you do not practice, you cannot get the idea to solve the exam question; I learn everything about numerical facts as well as logical and sensible thought processes via mathematics; I am motivated to do well in calculus courses by the precise interpretation and evaluation of mathematical issues; over 50% of the solution lies in carefully reading and comprehending mathematical problems; I already have a passion for mathematics and consider it to be a kind of intellectual sport; I think it is important because it will be beneficial for a real life. The mathematics can train the mind to calculate so it is important in the real life; I personally feel that I am having more knowledge if I solve one question I feel confident about my knowledge; I compute the speed, acceleration, and distance between cities using the mathematical equations and theories taught in calculus courses.

The provided words and phrases by students suggest that students' perceptions of calculus success impact their motivation for success in the subject. Some students stated that solving practice problems involving real-world applications can help them better understand mathematical theories, which in turn increases the drive of students to comprehend and do well in other future subjects in mathematics. The respondents who view calculus as a sport that stimulates the brain will anticipate being challenged and a sense of accomplishment during their educational journey.

During the interviews, the respondents used a number of words and expressions that sufficiently demonstrated their delight of calculus courses. The followings are some of the words and expressions:

> *R*eally, sometime the class will be long, and I cannot focus on the class and also it depends on the doctor; my feeling is not really good because some subjects are hard; my feeling depends on the instructor and type of mathematics. I feel motivated with instructors that explain mathematics (using diagrams). However, I dislike classes where instructors apply formulas only; I feel normal, sometime comfortable, sometime a little of stress during hard questions in courses of calculus; because I can grasp calculus courses clearly and because they do not require memorization, I enjoy them; since calculus assesses my IQ as well as reveals my thoughts and opinions, I have always enjoyed doing it and putting effort into it; due to my passion of calculations and problem-solving, I truly enjoy my time during the calculus lessons; I feel differently in calculus courses depending on the content covered by the professor and how well I comprehend it.

The previous expressions and words have shown that most students find calculus courses to be engaging and entertaining. According to the self-determination theory, students who are intrinsically driven exhibit delight and curiosity and have more chances to persevere and try in pursuit of their goals (Deci & Ryan, 1985). Other factors that contribute to students' enjoyment of calculus courses include receiving excellent instruction from motivated professors and understanding its applications in the real world.

If a specific task is deemed to be uninteresting or boring, the presence of intrinsic motivational elements alone could not be adequate if they are not supported with extrinsic motivation factors (Ryan & Deci, 2000). The respondents during the interviews used a variety of words and expressions that clearly show the extrinsic motivation of students in calculus courses. The followings are some of the words and expressions:

> I am an electrical engineer, so calculus courses are important for my career; definitely, vectors and matrices are important for artificial intelligence. Moreover, mathematics is required in physics for programming machines; calculus courses are from the most important courses to my future job. Mathematics and physics are fundamental to the field of civil engineering; calculus courses are important to my future in mechanical engineering; I am motivated to pass these courses since I should complete my mathematics requirements to earn my degree and get a job; my drive to succeed in calculus courses is fueled by receiving good grades.

The aforementioned statements confirm the consistent association between mathematics learning process and extrinsic motivators in calculus courses. It is obvious that grades and other external factors affect students' motivation to do well in calculus courses. Not only have the qualitative results improved and clarified the quantitative findings, yet they have also enhanced the knowledge of the factors that motivate students. As a result, mathematics professors, educators, and administrations of universities need to be aware that grades are used by students not just to reward themselves for their hard work and assess their mathematical competence, but they also act as an extrinsic source of motivation to students.

Theme II

The interviews helped in giving the respondents the chance to express their perceptions about themselves in terms of self-confidence and capacity to perform in calculus courses. Several terms and phrases were expressed by students reflecting mathematics self-concept in calculus courses:

> I think mathematics is more difficult than other courses because there is no formula sheet in the exam; I'm good at the basic of mathematics in high school. But now at university I found some courses to be hard because I studied all mathematics courses in Arabic in high school; I think I am a medium level student at mathematics; I am good at mathematics in calculus courses because I spent a lot of time to study and understand the concepts; mathematics is more difficult at the college since they go into details; I am not good at mathematics because it requires a good memory and constant revision; mathematics at the college level is easier because instructors take their time to explain concepts. In schools, teachers do not have time to explain and they just prepare students for exams. I finished all mathematics courses required for my degree. I will not take other math courses as I will self-learn any concepts when required; I think I'm good at mathematics because I was one from the best students at mathematics when I was in school. Also, it depends on each person as it is about different abilities; if I put in the effort and am passionate about the course, everything, even mathematics, is simple for me; my beliefs about my mathematical prowess affect how driven I am to succeed in calculus courses because anytime I do anything I dislike, I never give it my all; however, when I do something I enjoy and find appealing, I fully commit and strive to be the best in the world at it; my perceptions of how well I did in mathematics in high school are influenced by how well I did in mathematics in college. If my background in arithmetic had not been properly formed in high school, I would have trouble understanding what was being said in the lecture at university.

The aforementioned terms and phrases demonstrate how students' past encounters and experiences have influenced how they view their academic prowess, sense of self, likes, dislikes, and fears, as well as their objectives and accomplishments, all of which are connected to their motivation for success in calculus courses. Students' efforts to acquire mathematics in calculus courses have been found to be a key factor in students' mathematics self-concept, which is connected to their level of confidence. Also, some students have stated that their ability in mathematics gives them the chance to pick up the subject quickly and to tackle challenging mathematical issues with ease.

Theme III

The qualitative findings shed the light on new and different social and environment factors that were excluded from the quantitative approach. The respondents expressed several terms and phrases indicating the impact of supporting elements to their self-perception in mathematics and drive for success in courses of calculus. The supporting elements are related to the influence of parents, family members, peers, friends, classmates, instructors, educational resources, and other elements. The respondents used a variety of words and expressions during the interviews that evidently demonstrate the supporting factors' effects on students' perceptions of themselves in mathematics and their drive for success in calculus courses*:*

> My father is an engineer, so he teaches me mathematics more than any other course; sometime I ask my young brother for support because he is smart in mathematics. Sometimes I understand from him more than the teacher; I ask my friends when I encounter difficulty in mathematics understanding; I was recently motivated for calculus course accomplishment while I studied with a bunch of my classmates; I start by asking my instructor who simplifies the content if I face difficulty in understanding in calculus courses; the use of user-friendly online homework assignments to solve practice problems promotes my mathematic self-concept and motivation for success in calculus courses; I always ask my instructor who makes the content simple whenever I find the content to be difficult; the greatest way to succeed in calculus courses is to have a suitable learning environment supported with skilled and knowledgeable instructors; if I do not understand topics in calculus courses, I watch YouTube videos and use Google as well as other online educational resources.

Despite the fact that the influence of parents and siblings was not considered in the quantitative analysis in a specific measuring instrument, the aforementioned statements accurately capture the influence of parents and siblings on the growth of students' mathematical self-concept and their motivation for success in calculus courses. It is evident from the qualitative expressions that parental and sibling influence can either encourage or discourage students' behavior and motivation for success in calculus courses. Also, it is clear that classmates and college friends frequently connect, especially when they need assistance from one another in calculus classes. The aforementioned statements suggest that having good instructors, a straightforward and engaging teaching method, and participation in the college setting not only help students develop a healthy self-perception in mathematics yet also increase the motivation of students for success in calculus courses. Furthermore, it is obvious from the aforementioned phrases and expressions that online resources, such as online assignments, YouTube, Google, and other online educational tools, have a great impact on students' perceptions of themselves in mathematics and their motivation for success in calculus courses. Thus, professors and educators of mathematics as well as administrations of universities may employ the proposed online educational resources to encourage the motivation of students for success in calculus courses.

DISCUSSION

This study bridges the gap between the intrinsic and extrinsic motivation of students for success in calculus courses by developing and integrating two mathematical models. The significant input of this research study to the literature stems from the graph-based visualization, which is presented in **Figure 3** in order to graphically integrate the two developed mathematical models. The unique contribution of this research study to the literature is reflected by the two integrated mathematical models in **Figure 3**.

The two integrated models might be employed by mathematicians, educators, administrations of STEM programs, and higher education institutions to measure the intrinsic motivation of student for success in calculus courses and examine the impact of the measured level of students' intrinsic motivation on students' success in calculus courses.

It is observed in **Figure 3** that the intrinsic motivation of students for success in calculus courses in model I is integrated with model II. The impact of three independent variables, including the significance and need for calculus courses, students' perception of success in calculus courses, and students' delight of calculus courses, is analyzed on the global motivation of students for success in calculus courses in model II. **Figure 3** indicates that three independent variables represent intrinsic sources of motivation, which are imported from the dependent variable of the intrinsic motivation of students for success in calculus courses in model I. It is reported in the literature that persistence of students on learning calculus is influenced by their achievement emotions including delight and anxiety (Tang et al., 2021). As shown in **Figure 3**, the three independent variables of the significance and need for calculus courses, students' perception of calculus success, and students' delight of calculus courses explain 98.5% of the change in the global motivation of students for success in calculus courses. The qualitative findings expand on the quantitative findings since numerous phrases and concepts have been used by the respondents during the interviews that clearly demonstrate the impact of the significance and need for calculus courses, students' perception of calculus success, and students' delight of calculus courses on their motivation for success in calculus courses.

It is found that mathematics self-concept is an important factor that accounts for gender differences in students' performance level in advanced mathematics in the USA (Kodippili & Senaratne, 2022). The findings of model I suggest that the intrinsic motivation of students for success in calculus courses is predicted by five independent variables. It is clear that the cognitive aspect of mathematics self-concept in calculus courses has the best predictive power, followed by the affective aspect of mathematics self-concept in calculus courses, the projected careers, and earnings by students in the future, the quantity of courses of mathematics finished by students, and the age of students. The provided words and phrases by respondents in the qualitative findings suggest that students' perceptions of their academic ability, self-confidence, likes, dislikes, and fears, as well as their goals and achievements, have all been influenced by their prior experiences and interactions with the environment. These perceptions make up the mathematics self-concept of students, which are linked to their motivation for success in calculus courses. The most reliable indicator of students' success in college calculus was found to be their attitude toward mathematics. (Pyzdrowski et al., 2013). The qualitative results indicate that the influence of parents and siblings can either support or undermine students' behavior and motivation for success in calculus classes. Additionally, it is evident that friends and classmates routinely get in touch, particularly when they require help from one another in calculus courses. Parents and friends are discovered to have an impact on the of advanced mathematics courses completed by students (Gottfried et al., 2017). Furthermore, the availability of skilled instructors as well as online learning resources enhances the mathematics self-concept of students and their motivation for success in calculus courses. Students are found to enjoy taking online calculus courses, which increase their confidence (Al Rawashdeh et al., 2020) and this information matches with the study's findings on the use of online learning resources.

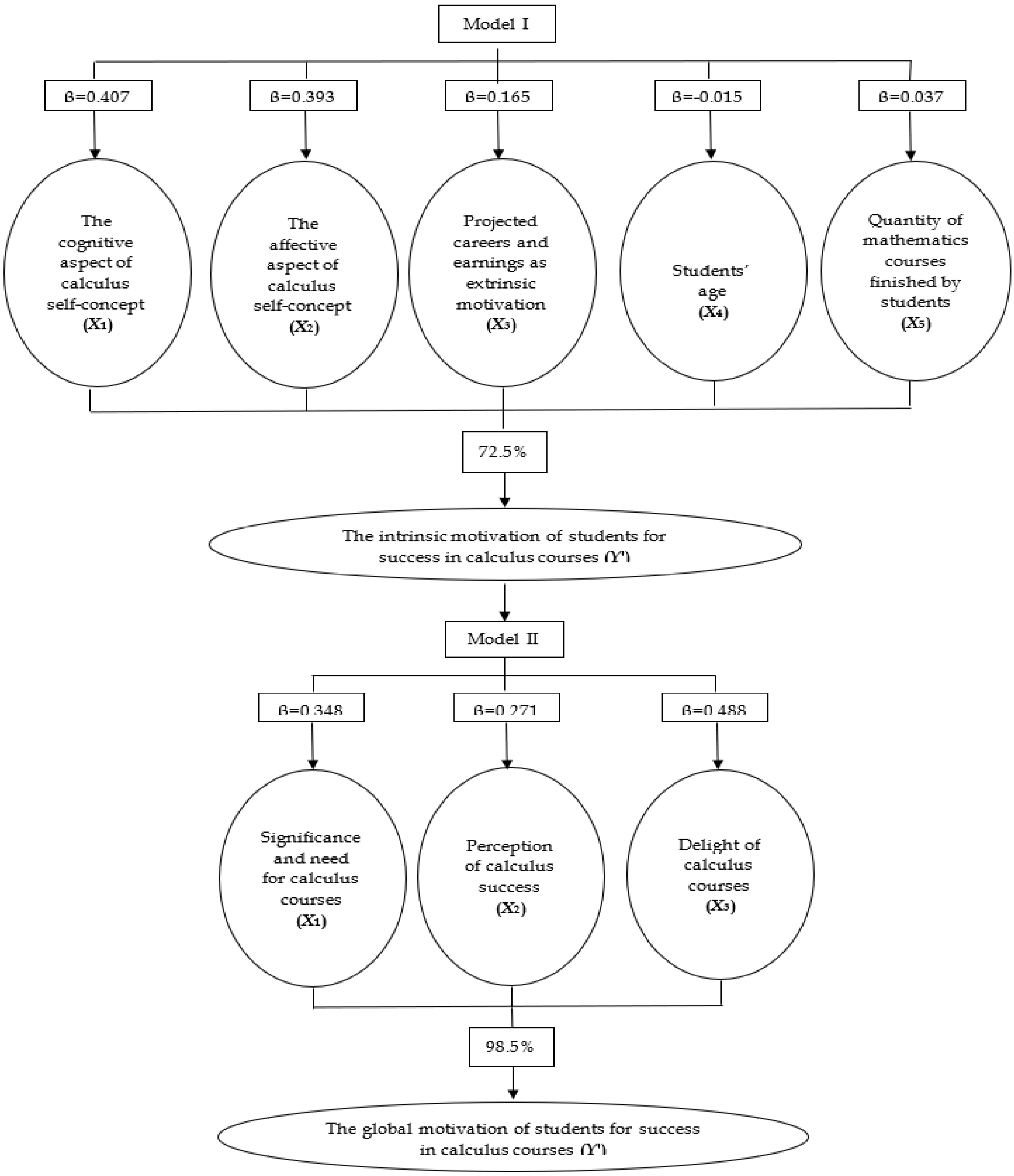

Figure 3. Graph-based visualization of the two integrated models (Source: Authors' own elaboration)

CONCLUSION

Despite of the fact that students' motivation, success, and performance in calculus courses have been examined in various research studies, few studies have shaded the light on modeling students' intrinsic and extrinsic motivation for success in calculus courses in STEM programs at higher education. Therefore, this study bridges the gap between the intrinsic and extrinsic motivation of students for success in calculus courses. Two mathematical models are designed to bridge the gap between the intrinsic and extrinsic motivation of students for success in calculus courses in STEM programs at a context of higher education. The geographical area of the study covers three universities located in the UAE, a developing nation and one of the region's and the Gulf Cooperation Council's brightest and fastest-rising suppliers of higher education. The aim of this study is to design and integrate two mathematical models to enhance the intrinsic and extrinsic motivation of students for success in calculus courses in STEM programs at a context of higher education. The two established models can be used by mathematics educators and professors, directors of mathematics programs, and administrators of academic institutions to gauge students' motivation levels and forecast their success in calculus courses.

To accomplish the purpose of the study, a mixed research method with an explanatory approach is used. The quantitative analyses are conducted to generate and integrate two mathematical models. The qualitative interviews are utilized to refined and enhance the quantitative finding. The results of regression analysis in model I indicate that the intrinsic motivation of students for success in calculus courses is predicted by five variables, which explain 72.5% of the change in the intrinsic motivation of students for success in calculus courses. The regression analysis findings in model II demonstrate that the global motivation of students for success in calculus courses is predicted by three independent variables generated from model I as sources of intrinsic motivation, which explain 98.5% of the change in the global motivation of students for success in calculus courses.

Based on the findings of model II, it is worthy to note that the global motivation of students for success in calculus courses is predicted by three independent variables of intrinsic motivation. It is obvious that students' delight of calculus courses has the highest predictive ability followed by the significance and need for calculus courses and students' perception of calculus success. The qualitative findings indicate that the expressions of students are divided into three themes including the motivation of students for success in calculus courses, the mathematics self-concept of students in calculus courses, and other supporting elements. Therefore, the following recommendations are provided to educators, mathematicians as well as managements of STEM programs at academic institutions to improve students' motivation for success in calculus courses.

1. Emphasizing the importance and necessity of calculus courses to students through their application in the daily lives of students outside the classroom.
2. Solving a lot of practice problems in order to enhance students' perception of their success in calculus courses.
3. Boosting students' enjoyment of calculus courses by focusing on the opportunities to learn new interesting and challenging things in courses of calculus.
4. Improving the cognitive aspect of students' mathematics perceptions by enhancing the self-confidence of students to learn advanced courses of calculus.
5. Enhancing the affective aspects of students' mathematics perceptions by encouraging students to explore new concepts and solve new problems in calculus courses.
6. Emphasizing the significant influence of parents, siblings, friends, classmates, skilled instructors, online learning resources on the mathematics self-concept of students and their motivation for success in calculus courses.

Limitations

This research was held in the UAE to assess student's mathematics self-concept and their motivation for success in calculus courses in the UAE. One of the limitations is the geographical focus of the study. Since all of the participants in the study have similar cultural traits that are similarly linked to gender difference, the study's chosen context does not allow for generalization. Therefore, it is recommended to implement the developed models in this research study in calculus courses offered at different universities in other continents as this may support in validating and generalizing the results of the research study. Furthermore, the majority of students in the study's sample do not major in mathematics, which is another restriction. Hence, future research may examine if students majoring in mathematics have higher self-concept in mathematics and greater motivation for success than students majoring in other fields.

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Ethical statement: Authors stated that the study was approved by the Research Ethics Committee on January 10, 2016 at one university with reference number ERS_2015_4244. The other two universities didn't have specific protocols. The directors of research granted their approvals via email or during the meeting with them. The instructors of calculus courses were approached and informed consents were obtained from students who were informed that their participation was voluntary and they had the right to withdraw at any time. The responses provided by students were treated with utmost confidentiality and were used for research purposes only.

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REFERENCES

Afgani, M. W., Suryadi, D., & Dahlan, J. A. (2019). Undergraduate students self-concept and their mathematics procedural knowledge: The relationship. *Infinity Journal, 8*(1), 99-108. https://doi.org/10.22460/infinity.v8i1.p99-108

Al Rawashdeh, A., Syam, M., & Serhan, D. (2020). Transitioning from face-to-face to online learning: Students' achievements and perceptions of learning calculus during COVID-19 pandemic. In I. Sahin, & M. Shelley (Eds.), *Educational practices during the COVID-19 viral outbreak: International perspectives* (pp. 221-238). ISTES Organization.

Ayebo, A., & Mrutu, A. (2019). An exploration of calculus students' beliefs about mathematics. *International Electronic Journal of Mathematics*

Education, 14(2), 385-392. https://doi.org/10.29333/iejme/5728

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review, 15*(1), 1-40. https://doi.org/10.1023/A:1021302408382

Deci, E. L. & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Springer. https://doi.org/10.1007/978-1-4899-2271-7

Easey, M., & Gleeson, J. (2016). *The relevance of mathematics: Leaders and teachers as gatekeeper for Queensland senior calculus mathematics* [Paper presentation]. Annual Meeting of the Mathematics Education Research Group of Australasia.

Erdogan, F., & Sengul, S. (2014). A study on the elementary school students' mathematics self-concept. *Procedia-Social and Behavioral Sciences, 152*, 596-601. https://doi.org/10.1016/j.sbspro.2014.09.249

Froiland, J. M., & Davison, M. L. (2016). The longitudinal influences of peers, parents, motivation, and mathematics course-taking on high school math achievement. *Learning and Individual Differences, 50*, 252-259. https://doi.org/10.1016/j.lindif.2016.07.012

Gottfried, M., Owens, A., Williams, D., Kim, H. Y., & Musto, M. (2017). Friends and family: A literature review on how high school social groups influence advanced math and science course taking. *Education Policy Analysis Archives, 25*, 62-62. https://doi.org/10.14507/epaa.25.2857

Hagman, J. E., Johnson, E., & Fosdick, B. K. (2017). Factors contributing to students and instructors experiencing a lack of time in college calculus. *International Journal of STEM Education, 4*(1), 1-15. https://doi.org/10.1186/s40594-017-0070-7

Hammoudi, M. M. (2019). Predictive factors of students' motivation to succeed in introductory mathematics courses: evidence from higher education in the UAE. *International Journal of Mathematical Education in Science and Technology, 50*(5), 647-664. https://doi.org/10.1080/0020739X.2018.1529339

Hammoudi, M. M. (2020). Measurement of students' mathematics motivation and self-concept at institutions of higher education: evidence of reliability and validity. *International Journal of Mathematical Education in Science and Technology, 51*(1), 63-86. https://doi.org/10.1080/0020739X.2019.1670369

Han, F. (2019). Self-concept and achievement in math among Australian primary students: Gender and culture issues. *Frontiers in Psychology, 10*, 603. https://doi.org/10.3389/fpsyg.2019.00603

Hine, G. (2019). Reasons why I didn't enroll in a higher-level mathematics course: Listening to the voice of Australian senior secondary students. *Research in Mathematics Education, 21*(3), 295-313. https://doi.org/10.1080/14794802.2019.1599998

Hoffman, N., Vargas, J., & Santos, J. (2009). New directions for dual enrolment: Creating stronger pathways from high school through college. *New Directions for Community Colleges, 145*, 43-58. https://doi.org/10.1002/cc.354

Hurdle, Z. B., Akbuga, E., & Schrader, P. (2022). Exploring calculus I students' performance between varying course times among other predictive variables. *International Electronic Journal of Mathematics Education, 17*(4), em0700. https://doi.org/10.29333/iejme/12234

Koch, D., & Herrin, G. D. (2006). Intervention strategy for improving success rates in calculus. *American Society for Engineering Education*. https://peer.asee.org/440

Kodippili, A., & Senaratne, D. C. (2022). Does the mathematics self-concept explain the gender-gap in advanced mathematics achievement among US secondary school students? *Journal of Research Initiatives, 6*(1), 2.

Leach, L. F., Henson, R. K., Odom, L. R., & Cagle, L. S. (2006). A reliability generalization study of the self-description questionnaire. *Educational and Psychological Measurement, 66*(2), 285-304. https://doi.org/10.1177/0013164405284030

Lim, S. Y., & Chapman, E. (2013). Development of a short form of the attitudes toward mathematics inventory. *Educational Studies in Mathematics, 82*(1), 145-164. https://doi.org/10.1007/s10649-012-9414-x

Liu, E. Z. F., & Lin, C. H. (2010). The survey study of mathematics motivated strategies for learning questionnaire (MMSLQ) for grade 10-12 Taiwanese students. *The Turkish Online Journal of Educational Technology, 9*(2), 221-233.

Lovell, M. C. (2004). *Economics with calculus*. World Scientific Publishing Company. https://doi.org/10.1142/5523

Marsh, H. W., & O' Neil, R. (1984). Self-description questionnaire III: The construct validity of multidimensional self-concept ratings by late adolescents. *Journal of Educational Measurement, 21*(2), 153–173. https://doi.org/10.1111/j.1745-3984.1984.tb00227.x

Matthews, A. R., Hoessler, C., Jonker, L., & Stockley, D. (2013). Academic motivation in calculus. *Canadian Journal of Science, Mathematics and Technology Education, 13*(1), 1-17. https://doi.org/10.1080/14926156.2013.758328

Minichiello, A., & Hailey, C. (2013, October). Engaging students for success in calculus with online learning forums. In *Proceedings of the 2013 IEEE Frontiers in Education Conference* (pp. 1465-1467). IEEE. https://doi.org/10.1109/FIE.2013.6685077

Monteiro, V., Mata, L., & Peixoto, F. (2015). Intrinsic motivation inventory: Psychometric properties in the context of first language and mathematics learning. *Psicologia: Reflexão e Crítica* [*Psychology: Reflection and Criticism*], *28*(3), 434-443. https://doi.org/10.1590/1678-7153.201528302

Neuhauser, C., & Roper, M. L. (2004). *Calculus for biology and medicine*. Pearson.

Park, E. S., Ngo, F., & Melguizo, T. (2021). The role of math misalignment in the community college STEM pathway. *Research in Higher Education, 62*(4), 403-447. https://doi.org/10.1007/s11162-020-09602-y

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). A manual for the use of the motivated strategies for learning questionnaire (MSLQ). *National Center for Research to Improve Postsecondary Teaching and Learning*. https://files.eric.ed.gov/fulltext/ED338122.pdf

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational and Psychological Measurement, 53*(3), 801-813. https://doi.org/10.1177/0013164493053003024

Pyzdrowski, L. J., Sun, Y., Curtis, R., Miller, D., Winn, G., & Hensel, R. A. (2013). Readiness and attitudes as indicators for success in college calculus. *International Journal of Science and Mathematics Education, 11*(3), 529-554. https://doi.org/10.1007/s10763-012-9352-1

Rasmussen, C., & Ellis, J. (2013). Who is switching out of calculus and why. In *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education* (pp. 73-80). PME.

Rickard, B., & Mills, M. (2018). The effect of attending tutoring on course grades in calculus I. *International Journal of Mathematical Education in Science and Technology, 49*(3), 341-354. https://doi.org/10.1080/0020739X.2017.1367043

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54-67. https://doi.org/10.1006/ceps.1999.1020

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research, 46*(3), 407-441. https://doi.org/10.3102/00346543046003407

Sikora, J., & Pitt, D. G. (2019). Does advanced mathematics help students enter university more than basic mathematics? Gender and returns to year 12 mathematics in Australia. *Mathematics Education Research Journal, 31*(2), 197-218. https://doi.org/10.1007/s13394-018-0249-3

Sonnert, G., & Sadler, P. M. (2014). The impact of taking a college pre-calculus course on students' college calculus performance. *International Journal of Mathematical Education in Science and Technology, 45*(8), 1188-1207. https://doi.org/10.1080/0020739X.2014.920532

Stanberry, M. L. (2018). Active learning: a case study of student engagement in college calculus. *International Journal of Mathematical Education in Science and Technology, 49*(6), 959-969. https://doi.org/10.1080/0020739X.2018.1440328

Tang, D., Fan, W., Zou, Y., George, R. A., Arbona, C., & Olvera, N. E. (2021). Self-efficacy and achievement emotions as mediators between learning climate and learning persistence in college calculus: A sequential mediation analysis. *Learning and Individual Differences, 92*, 102094 https://doi.org/10.1016/j.lindif.2021.102094

Tanner, H., & Jones, S. (2000). Scaffolding for success: Reflective discourse and the effective teaching of mathematical thinking skills. *Research in Mathematics Education, 2*(1), 19-32. https://doi.org/10.1080/14794800008520065

Tapia, M., & Marsh, G. E. (2002). *Confirmatory factor analysis of the attitudes toward mathematics inventory* [Paper presentation]. Annual Meeting of the Mid-South Educational Research Association.

Ubuz, B. (2011). Factors associated with success in a calculus course: an examination of personal variables. *International Journal of Mathematical Education in Science and Technology, 42*(1), 1-12. https://doi.org/10.1080/0020739X.2010.500694

Watt, H. M. G., Eccles, J. S., & Durik, A. M. (2006), The leaky mathematics pipeline for girls: A motivational analysis of high school enrolments in Australia and the USA. *Equal Opportunities International, 25*(8), 642-659. https://doi.org/10.1108/02610150610719119

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review, 92*, 548-573. https://doi.org/10.1037/0033-295X.92.4.548

Weinstock, R. (1974). *Calculus of variations: with applications to physics and engineering*. Courier Corporation.

Zakariya, Y. F. (2017). Development of attitudes towards mathematics scale (ATMS) using Nigerian data-factor analysis as a determinant of attitude subcategories. *International Journal of Progressive Education, 13*(2), 74-84.