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Relations of mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy to STEM career choice: A structural equation modeling approach

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Abstract

Several key factors have emerged from the literature contributing to the explanation of STEM participation (or lack of), including mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy. Despite the research on the relations of these variables to career interest, few studies have integrated them and examined their intertwined relations in one model. The purpose of this study was to use a structural equation modeling approach to answer the central question: To what extent are the factors of mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy related to each other and a STEM career choice? The results highlight a key finding that mathematics identity serves as a full mediator between mathematics mindset and STEM career interest as well as between mathematics anxiety and STEM career interest.

KEYWORDS

mathematics anxiety, mathematics identity, mathematics mindset, mathematics self-efficacy, STEM career choice

1 | INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) occupations are in great demand in the United States, with a projected growth rate of 8.9% from 2014 to 2024 (Noonan, 2017). However, a shortage of individuals entering the STEM workforce has been a concern over recent decades and has generated an abundance of research and discussions on ways to encourage STEM participation. Several key affective and motivational factors emerged from the literature that contributed to explaining STEM participation (or lack of), including mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy. Mathematics mindset has been described as an individual's belief about whether one's intellectual abilities in mathematics are fixed or whether they are able to be developed over time (Dweck, 2000, 2006). Mathematics anxiety is known as an individual's feelings of fear in performing mathematics-related tasks (Ashcraft, 2002). Mathematics identity refers to one's perceptions of their own relationship to mathematics (Cribbs et al., 2015). Finally, the term mathematics self-efficacy is used to describe an individual's judgments about their own capability to succeed in mathematics (Chamberline, 2010; Lent et al., 1997).

Previous research has examined the relationship between these affective and motivational variables and their relationship to career interest. For example, the connection between mathematics anxiety, mathematics self-efficacy, and STEM career choice has been well established (Ashcraft, 2002; Ashcraft & Krause, 2007; Chipman et al., 1992; Nugent et al., 2014; Zeldin et al., 2008). There is also evidence that mathematics mindset (Burkley et al., 2010) and mathematics identity (Cribbs et al., 2016; Godwin et al., 2016) influences career interest. However, to the best of our knowledge, no studies have integrated all these variables and examined their intertwined relations in one model, which was the purpose of this study. Specifically, we were interested in investigating how mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy related to each other and a STEM career choice.

2 | LITERATURE REVIEW

Among the four aforementioned affective and motivational variables, mathematics anxiety and mathematics self-efficacy are the most studied in their relation to STEM participation. A large number of studies have shown that mathematics anxiety and mathematics self-efficacy impact STEM participation in that individuals with low mathematics self-efficacy (Catsambis, 1994; Lent et al., 1991; Pajares & Graham, 1999; Zeldin et al., 2008) or/and high mathematics anxiety (Ashcraft, 2002; Ashcraft & Krause, 2007; Chipman et al., 1992) tend to avoid mathematics, either by taking fewer mathematics courses or by choosing non-mathematics-related occupations.

Mathematics anxiety and mathematics self-efficacy have also been shown to be related to each other. Mathematics anxiety is negatively correlated with mathematics self-efficacy (Griggs et al., 2013; Lopez & Lent, 1992; Pajares & Miller, 1994). Furthermore, the literature has shown that the negative relationship found between mathematics anxiety and mathematics self-efficacy could be bi-directional, indicating that one influences the other and vice versa. On the one hand, theoretically, anxiety is a physiological source of self-efficacy development (Bandura, 1997), and high mathematics anxiety leads to or predicts lowered mathematics self-efficacy (Lopez & Lent, 1992; Meece et al., 1990), indicating a causal relationship. On the other hand, there is evidence that mathematics self-efficacy, in turn, predicts the level of mathematics anxiety; or, in other words, lowered mathematics self-efficacy leads to elevated mathematics anxiety (Akin & Kurbanoglu, 2011; Pajares & Kranzler, 1995). In addition, both mathematics anxiety (Ashcraft, 2002; Ashcraft & Krause, 2007; Chipman et al., 1992) and mathematics self-efficacy (Bandura et al., 2001; Nugent et al., 2014; Zeldin et al., 2008) contribute to the explanation of STEM career choice. Consistent with the reciprocal relationship between mathematics anxiety and mathematics self-efficacy discussed previously, there is evidence that the influence of mathematics anxiety to career interest is mediated through mathematics self-efficacy (i.e., mathematics anxiety influences mathematics self-efficacy, which in turn influences career interest; Pajares & Kranzler, 1995), or that the influence of mathematics self-efficacy on major choice is mediated through mathematics anxiety (i.e., mathematics self-efficacy influences mathematics anxiety, which in turn influences major choice; Hackett, 1985). However, a recent study with middle school students did not support the reversed relationship from mathematics self-efficacy to mathematics anxiety in a model predicting mathematics and science career interest (Huang et al., 2019). In sum, there is an intertwined relationship among mathematics anxiety, mathematics self-efficacy, and STEM career choice, including the direct effect and the indirect effect (through mediation) from mathematics anxiety and mathematics self-efficacy to career choice, respectively.

More recent literature has shown evidence that both mathematics mindset and mathematics identity also relate to career interest. With regards to mathematics mindset, there are two opposing views or theories of intellectual abilities, which are (a) the entity theory that views intelligence as innate and unchangeable (i.e., fixed mindset); and (b) the incremental theory that views intelligence as an entity that can grow with effort (i.e., growth mindset; Dweck, 2006, 2008). A growing body of literature has indicated that having a growth mindset predicts adolescents' achievements in mathematics and science (Blackwell et al., 2007; Dweck, 2006, 2008) and choice of mathematics courses as students transitioned to middle school (Romero et al., 2014). Mathematics identity, how one views themselves with respect to mathematics, has been defined and conceptualized in a variety of ways in the literature. In her literature review of identity research in mathematics education, Darragh (2016) identified three distinct views of identity: "an action or an acquisition, a process, or something we have inside of ourselves" (p. 26). These varying perspectives are not isolated to mathematics education but are also evident in the broader STEM education identity literature, with commonalities in ways identity is defined and theoretically positioned between the disciplines as well (Godwin et al., 2020). Drawing from Gee's (2000) work, a core identity perspective is used when exploring identity in this study, with identity being viewed as thickening over time. Drawing from prior work related to science identity (Carlone & Johnson, 2007; Hazari et al., 2010), a measure for mathematics identity was previously developed and items validated (Cribbs et al., 2015, 2016). This measure is comprised of the following two sub-constructs at the college level: (a) recognition (how individuals perceive others to view them in relation to mathematics) and (b) interest (an individual's desire to think about and learn mathematics). Similar to other research indicating the importance of disciplinary (engineering and science) identity on student career goals or interest (Godwin et al., 2016; Hazari et al., 2010; Jones et al., 2016), research notes the importance of mathematics identity on students' career interest (Cribbs et al., 2016, 2020).

Furthermore, mathematics mindset has been shown to be related to mathematics self-efficacy. Previous empirical research has indicated that having a growth mindset led to enhanced self-efficacy, while having a fixed mindset had either a detrimental or no effect on self-efficacy development (Bråten & Strømsø, 2005; Jourden et al., 1991; Wood & Bandura, 1989; Young & Urdan, 1993). In the domain of mathematics, there is also limited empirical evidence that having a fixed mathematics mindset resulted in avoidance of mathematics-related career interests (Burkley et al., 2010). The effect of growth mindset on career interest could also be mediated through self-efficacy as demonstrated in a recent study including middle school students (Huang et al., 2019).

3 | THE PRESENT STUDY

Despite the previous research on the relationship between these affective variables and their relationship to career interest, to the best of our knowledge, no studies have integrated all four of them and examined their intertwined relations in one model. For this study, our central research question was: To what extent are the factors of mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy related to each other and a STEM career choice? We hypothesized that in an integrated model, the effect of mathematics anxiety and mathematics mindset on STEM career interest would be partially mediated through mathematics self-efficacy, which in turn would be partially mediated through mathematics identity in its impact on career interest (Figure 1). As discussed earlier, previous research established the mediating role of self-efficacy between anxiety and career interest (e.g., Pajares & Kranzler, 1995) and that between growth mindset and career interest (e.g., Huang et al., 2019). In addition, we proposed that mathematics identity would play a mediating role between mathematics self-efficacy and career interest. It seems reasonable to argue that as students' mathematics self-efficacy increases, they would establish a higher level of mathematics identity, by increasing their sense of belonging and subsequently their desire to think and learn about mathematics, which, in turn, would contribute to participation in STEM career interests. By better understanding the relationships among these four constructs and their influence on career choice, we hope that it will allow the field to better strategize how to encourage students to consider careers in STEM fields.

4 | METHODS

4.1 | Participants

The participants in this study were 836 first-year undergraduate students at two public universities in the Eastern part of the United States. Each university had a total of more than 20,000 undergraduate and graduate students enrolled and had more female students than male students. Specifically, for the undergraduate population, there were about 58% females in one university and 55% females in other. An email invitation was sent through a university-supported mass email system to all first-year students enrolled at either of the two universities (total $\approx$ 7,594) asking them to participate in the study through the completion of an online survey. Participants could complete the survey at a time and place of their choice during the study period, and they were eligible for a drawing for one of five $50 gift cards by participating in this survey. The survey return rate was about 11% (836 out of 7,594). We chose to survey only first-year students because we wanted to better understand students' perspectives and career interest as they were first entering college, prior to being influenced by their collegiate experiences. This would better inform us of what types of experiences might be useful at the beginning of college in order to encourage selection and persistence in STEM fields. About 21% of the participants identified as male, 71% identified as female, and 8% did not respond. With regard to race and ethnicity, 75% identified as Caucasian, 5% as African American, 4% as Multi-racial, 3% as Asian, 2% as Hispanic, 2% as Other, less than 1% as American Indian or Alaska American, and 9% did not respond.

4.2 | Instruments

The survey pulled items from existing research to measure four constructs concerning perceptions of mathematics.

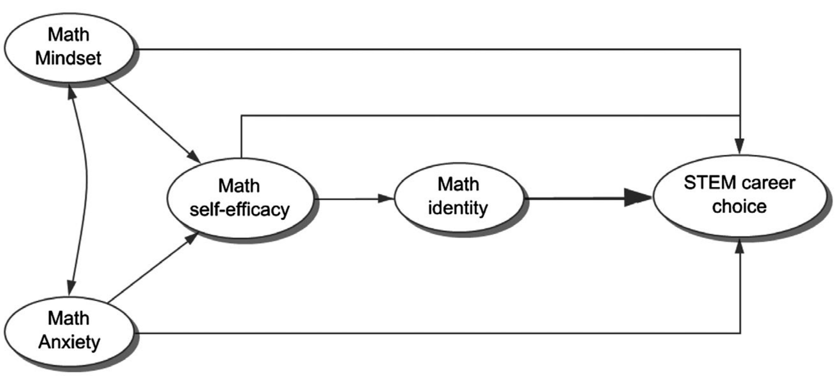

FIGURE 1 Theoretical model integrating math mindset, math anxiety, math self-efficacy, and math identity in predicting STEM career choice

Mathematics mindset was measured by eight items developed by Dweck (2000, 2008). Mathematics anxiety was measured by nine items (Betz, 1978). Mathematics identity was measured by six items by Cribbs et al. (2015), and mathematics self-efficacy was measured by 12 items adapted from the Confidence in Learning Mathematics sub-scale of Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). It is worth noting that this self-efficacy scale is not task specific as originally proposed by Bandura (1997), but more of a mathematics domain-level measurement used in previous research (e.g., Chamberline, 2010).

All the items used a 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree) in this study. A complete list of the items used can be found in Table 1. Cronbach's alpha was used to calculate the internal consistency for each of the four factors yielding $\alpha = 0.90$ for mindset, $\alpha = 0.88$ for anxiety, $\alpha = 0.94$ for self-efficacy, and $\alpha = 0.95$ for identity. Career interest was measured by a multiple choice question asking students to select from a list of STEM (e.g., engineer, chemist) and non-STEM (e.g., social scientist, other non-science/math-related career) career choices the one that best described their current career interest (only one option from the list being permitted). This variable was recoded so that a STEM career interest represented 1 and a non-STEM career choice represented 0. Questions gathering demographic information (age, gender, ethnicity, etc.) were also included on the survey.

4.3 | Data analysis

All survey responses were recorded in the online system and downloaded for data analyses at the conclusion of data collection. Structural equation modeling (*SEM*) through path modeling was used to explore the relationship that mathematics-related constructs had with one another and with a STEM career choice. Because there is not an a priori model for the variables being tested, a model generation approach was taken for this study (Kline, 2011). *SEM* involves testing the measurement model and then testing the structural model. To test the measurement model, analysis began with a correlation test between factors followed by a confirmatory factor analysis (CFA) using prior research for how items loaded on each factor. Pearson's correlation coefficients were interpreted as $\pm$ 0.1 representing a small effect, $\pm$ 0.3 representing a medium effect, and $\pm$ 0.5 representing a large effect (Field et al., 2012). Performing a Hawkins test of normality and homoscedasticity, followed by a nonparametric test, we found that although the data were not normally distributed, it was missing completely at random. It is also important to note that, while missing data were low for the constructs being measured (less than 1%), there was a larger percent of data missing for the career choice variable (11%). Two factors could have contributed to this issue: (a) students were surveyed in the first semester of their undergraduate program when they might not have solidified their career goals and thus left the item blank and (b) the question was toward the end of the survey and some survey fatigue might have been experienced by participants.

Because our endogenous variable (career choice) was dichotomous, we used diagonally weighted least squares (DWLS) to estimate the model parameters. This method automatically created robust standard errors, adjusting for non-normally distributed data and is appropriate if only one dependent variable is included in the model and values are missing at random (Asparouhov & Muthén, 2010), which is appropriate for estimating our model. This technique does not automatically address missing data as with full information maximum likelihood (FIML) estimation. For this reason, random imputation was conducted to create a complete data vector for variables in the model. Mediation was explored through direct and indirect effects. Drawing from literature, the following fit indices were reported in this study with recommended threshold levels noted in parentheses: (a) NNFI (>0.90), (b) CFI (>0.90), (c) RMSEA (<0.08), and (d) SRMR (<0.05; Awang, 2015; Schumacker & Lomax, 2016). Full information maximum likelihood estimation was used. All analysis was done using R statistical software (R Development Core Team, 2016), with the Lavaan package used for CFA and *SEM* (Rosseel, 2012).

5 | RESULTS

5.1 | Descriptive results

Table 1 provides a list of the descriptive statistics for the items for each construct. Results indicate that, in general, participants had positive beliefs with means greater than 2.50.

Table 2 provides a list of the possible career choices available on the survey and the corresponding number of responses to the item "Which BEST describes your current career choice." Selecting a STEM career choice was coded as 1 and a non-STEM career choice as 0. Twenty-two percent of the sample selected a STEM career choice with "Other science/math-related career" and engineering representing half of the participant sample.

5.2 | Measurement model

The Pearson's correlations matrix for all four factors is shown in Table 3 including the corresponding descriptive statistics for each factor.

The correlation matrix indicated that all the factors were significantly correlated with one another; however, some of these correlations were stronger than others. There was a

TABLE 1 Items from survey and descriptive statistics for observed variables

Latent variable	Indic. Variable	Survey item	N	M	SD
Math Mindset	Q3_1	You have a certain amount of math intelligence, and you cannot really do much to change it	836	2.71	1.13
	Q3_2	Your math intelligence is something about you that you cannot change very much	835	2.62	1.12
	Q3_3	No matter who you are, you can significantly change your math intelligence level	836	3.57	1.04
	Q3_4	To be honest, you cannot really change how intelligence you are in math	834	2.44	1.08
	Q3_5	You can learn things, but you cannot really change your basic math intelligence	833	2.64	1.12
	Q3_6	No matter how much math intelligence you have, you can always change it quite a bit	834	3.59	0.97
	Q3_7	You can always substantially change how intelligent you are in math.	833	3.41	1.03
	Q3_8	You can change even your basic math intelligence level considerably	834	3.63	0.98
Math Anxiety	Q4_1	It would not bother me to take more math classes	833	3.12	1.38
	Q4_2	I get uptight during math tests	835	3.12	1.34
	Q4_3	I have usually been at ease during math tests	835	2.66	1.29
	Q4_4	My mind goes blank and I am unable to think clearly when doing math	835	2.74	1.33
	Q4_5	I usually do not worry about my ability to solve math problems	833	2.93	1.23
	Q4_6	Math makes me feel uncomfortable and nervous	835	2.79	1.40
	Q4_7	I almost never get uptight, while taking math tests	835	2.65	1.28
	Q4_8	I get a sinking feeling when I think of trying hard math problems	834	2.91	1.37
	Q4_9	Math makes me feel uneasy and confused	831	2.88	1.40
Math Identity	Q5_1	I enjoy learning math	834	3.12	1.33
	Q5_2	Math is interesting	833	3.14	1.30
	Q5_3	I look forward to taking math	835	2.65	1.31
	Q5_4	I see myself as a math person	833	2.64	1.38
	Q5_5	My parents/relatives/friends see me as a math person	833	2.76	1.40
	Q5_6	My teachers see me as a math person	834	2.79	1.29
Math Self-Efficacy	Q6_1	Generally, I have felt secure about attempting math	834	3.30	1.22
	Q6_2	I am not good at math	834	2.79	1.33
	Q6_3	I am sure I could do advanced work in math	834	3.17	1.24
	Q6_4	I am sure I that I can learn math	831	3.93	0.95
	Q6_5	I am not the type to do well in math	832	2.63	1.26
	Q6_6	I think I could handle more difficult math	833	3.18	1.22
	Q6_7	For some reason even though I study, math seems unusually hard for me	834	2.86	1.30
	Q6_8	I do not think I could do advanced math	834	2.70	1.29
	Q6_9	I can get good grades in math	835	3.81	1.00
	Q6_10	Math has been my worst subject	831	2.71	1.44
	Q6_11	I have a lot of self-confidence when it comes to math	835	2.92	1.23
	Q6_12	Most subjects I can handle ok, but I have a knack of mucking up math	834	2.84	1.25

Note: All items are measured on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

TABLE 2 Number of students selecting each career goal

Career goal	Number	Percent of sample
Non-STEM (e.g., lawyer and business person)	558	67
STEM		
Engineer	43	5
Environmental scientist	16	2
Chemist	10	1
Physicist	4	<1
Biologist	14	2
Computer scientist/IT	20	2
Mathematician	3	<1
Math teacher	16	2
Science teacher	7	1
Other science/math-related career (e.g., actuary and geologist)	54	6
STEM Total	187	22

TABLE 3 Correlations between affective factors ($N = 836$)

Variables	Mindset	Anxiety	Self-efficacy	Identity
1. Mindset	–			
2. Anxiety	−0.43***	–		
3. Self-efficacy	0.51***	−0.85***	–	
4. Identity	0.37***	−0.73***	0.82***	–
M	3.47	3.01	3.32	2.85
SD	0.82	0.96	0.97	1.19

*$p < .05$; **$p < .01$; ***$p < .001$.

strong, positive correlation between self-efficacy and identity ($r = 0.82$, $p < .001$) and strong, negative correlation between self-efficacy and anxiety ($r = -0.85$, $p < .001$). A statistically significant moderate, negative correlation was found between mindset and anxiety ($r = -0.43$, $p < .001$). Mindset and identity also had a moderate, positive correlation ($r = 0.37$, $p < .001$).

CFA was conducted with all but one item being significant. The one item that did not load well (0.06, $p = .238$) was with the anxiety construct (Q4_1), "It wouldn't bother me at all to take more math classes." For this reason, this item was removed from the model. All other items loaded as expected and were retained in the model. Results of the CFA are shown in Table 4 along with the standardized factor loadings, item reliability for indicator variables, fit indices, and construct reliability and average variance extracted from latent variables.

Item reliability (R^2) ranged from 0.30 to 0.83. Convergent validity (the extent to which two constructs are related) was also calculated for each of the factors in the CFA analysis, with correlational values being 0.3 or greater.

5.3 | Structural model

We first tested a model with direct and indirect effects from mathematics mindset and mathematics anxiety to career choice, having hypothesized that there was partial mediation through self-efficacy. Both of these direct effects were not significant: mathematics mindset → STEM career choice ($\beta = 0.042$, $p = .497$) and mathematics anxiety → STEM career choice ($\beta = -0.118$, $p = .540$). However, the indirect effect of mindset and anxiety through self-efficacy was significant. The results of the revised model excluding the nonsignificant pathways are shown in Figure 2, with standardized coefficients being reported. While SRMR and RMSEA fit indices were within the recommended threshold, NNFI and CFI were below 0.90 at 0.82 and 0.84, respectively, indicting there were still issues with model fit. As hypothesized, self-efficacy related negatively with anxiety ($\beta = -0.879$, $p < .001$). Self-efficacy was also positively related to mathematics mindset ($\beta = 0.115$, $p < .001$). Mathematics identity was positively related to self-efficacy ($\beta = 0.883$, $p < .001$) and STEM career choice was positively related to mathematics identity ($\beta = 0.716$, $p < .001$). However, the direct effect between mathematics self-efficacy and STEM career choice was negative, ($\beta = -0.395$, $p < .001$), hinting at possible issue with multicollinearity. The very high correlation found between mathematics self-efficacy and mathematics identity as well as mathematics self-efficacy and mathematics anxiety (greater than 0.80) may be an indicator of multicollinearity, but this indicator alone is not sufficient evidence that this is the case (Field et al., 2012). To further test whether or not a multicollinearity issue existed in the model, the variance inflation factor (VIF) and tolerance were found for the constructs. Mathematics self-efficacy had a tolerance of 0.16 (less than the recommended 0.20) and a VIF of 6.23 (higher than the recommended maximum of 4; Hair et al., 2010). These results, along with several fit indices being below acceptable thresholds, led us to test a modified model excluding mathematics self-efficacy.

Results of our final model excluding mathematics self-efficacy are shown in Figure 3, with standardized coefficients being reported. Fit indices indicated a good fit with all values being within the recommended threshold. Identity was positively related to mathematics mindset ($\beta = 0.093$, $p < .001$) and negatively related to mathematics anxiety ($\beta = -0.763$, $p < .001$). STEM career choice was positively related to mathematics identity ($\beta = 0.367$, $p < .001$). However, a direct effect between mathematics mindset and career choice was not significant ($\beta = 0.006$, *ns*); the same was true for mathematics anxiety and career choice ($\beta = 0.173$, *ns*). For this reason, these two pathways were excluded from the final model.

TABLE 4 CFA estimates and fit indices

Latent variable	Indicator variable	Std. factor loading	Standard error	Item reliability (R^2)	Construct reliability	Average variance extracted
Mindset	Q3_3	0.75***	0.018	0.56	0.88	0.62
	Q3_6	0.83***	0.014	0.71		
	Q3_7	0.84***	0.014	0.71		
	Q3_8	0.78***	0.016	0.61		
Anxiety	Q4_2	0.76***	0.015	0.58	0.92	0.57
	Q4_3	0.70***	0.018	0.49		
	Q4_4	0.80***	0.013	0.64		
	Q4_5	0.54***	0.025	0.30		
	Q4_6	0.89***	0.008	0.79		
	Q4_7	0.61***	0.023	0.37		
	Q4_8	0.81***	0.013	0.66		
	Q4_9	0.90***	0.007	0.83		
Identity	Q5_1	0.88***	0.009	0.77	0.95	0.75
	Q5_2	0.83***	0.012	0.69		
	Q5_3	0.88***	0.009	0.77		
	Q5_4	0.91***	0.007	0.83		
	Q5_5	0.86***	0.010	0.74		
	Q5_6	0.83***	0.012	0.69		
Self-efficacy	Q6_1	0.78***	0.014	0.61	0.94	0.59
	Q6_2	0.84***	0.011	0.71		
	Q6_3	0.77***	0.015	0.59		
	Q6_4	0.56***	0.024	0.31		
	Q6_5	0.85***	0.010	0.72		
	Q6_6	0.82***	0.012	0.67		
	Q6_7	0.86***	0.010	0.74		
	Q6_8	0.82***	0.012	0.67		
	Q6_9	0.59***	0.023	0.35		
	Q6_10	0.84***	0.011	0.72		
	Q6_11	0.71***	0.018	0.50		
	Q6_12	0.70***	0.018	0.49		
$N = 836$						
Model $x^2 = 2{,}248$		$Df = 399$				
Null Model $x^2 = 21{,}846$		$Df = 435$				
NNFI	0.91					
CFI	0.91	90% CI				
RMSEA	0.074	0.071, 0.077				
SRMR	0.040					

Abbreviations: CFI, comparative fit index; CI, confidence interval; *Df*, degrees of freedom; NNFI, non-normed fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual.

***$p < .001$.

6 | DISCUSSION

The present study examined the association of mathematics mindset, mathematics anxiety, mathematics identity, and mathematics self-efficacy to STEM career choice using a structural modeling approach. We proposed an integrated model that the effect of mathematics anxiety and mathematics mindset on STEM career interest would be partially

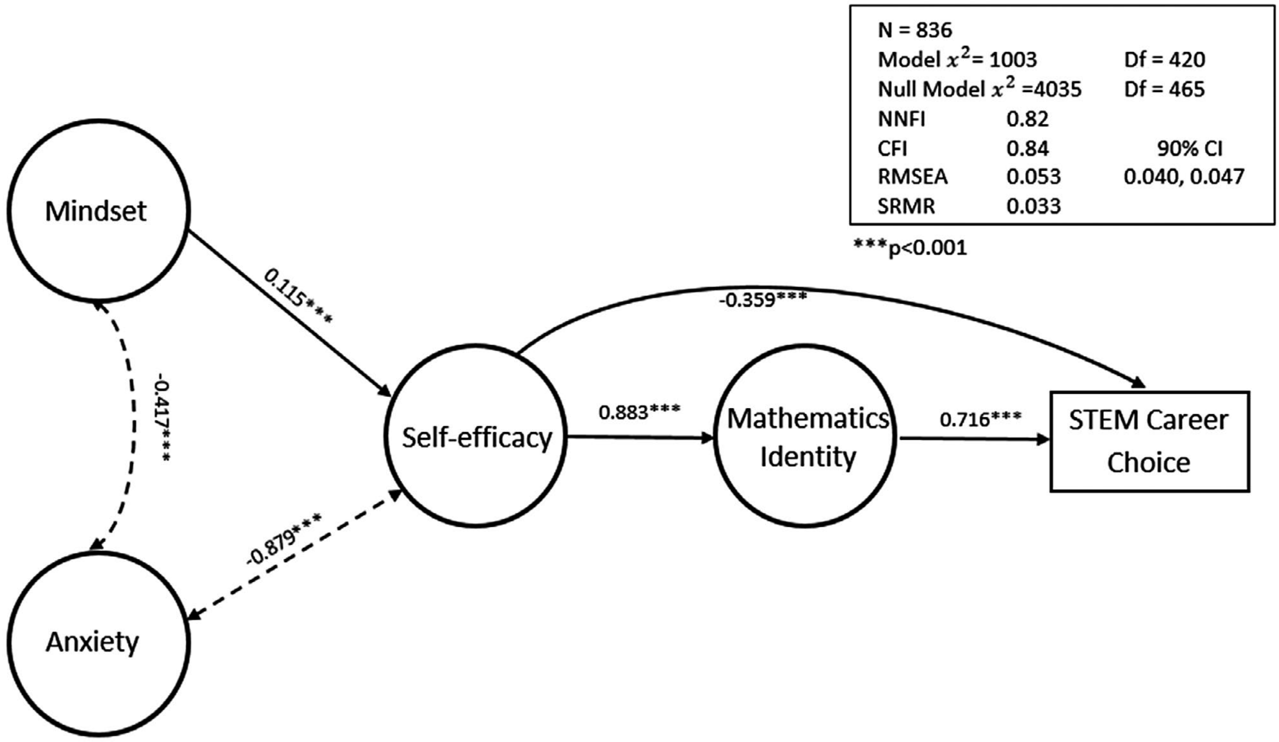

FIGURE 2 *SEM* results. NNFI, non-normed fit index; CFI, comparative fit index; CI, confidence interval; Df, degrees of freedom; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual

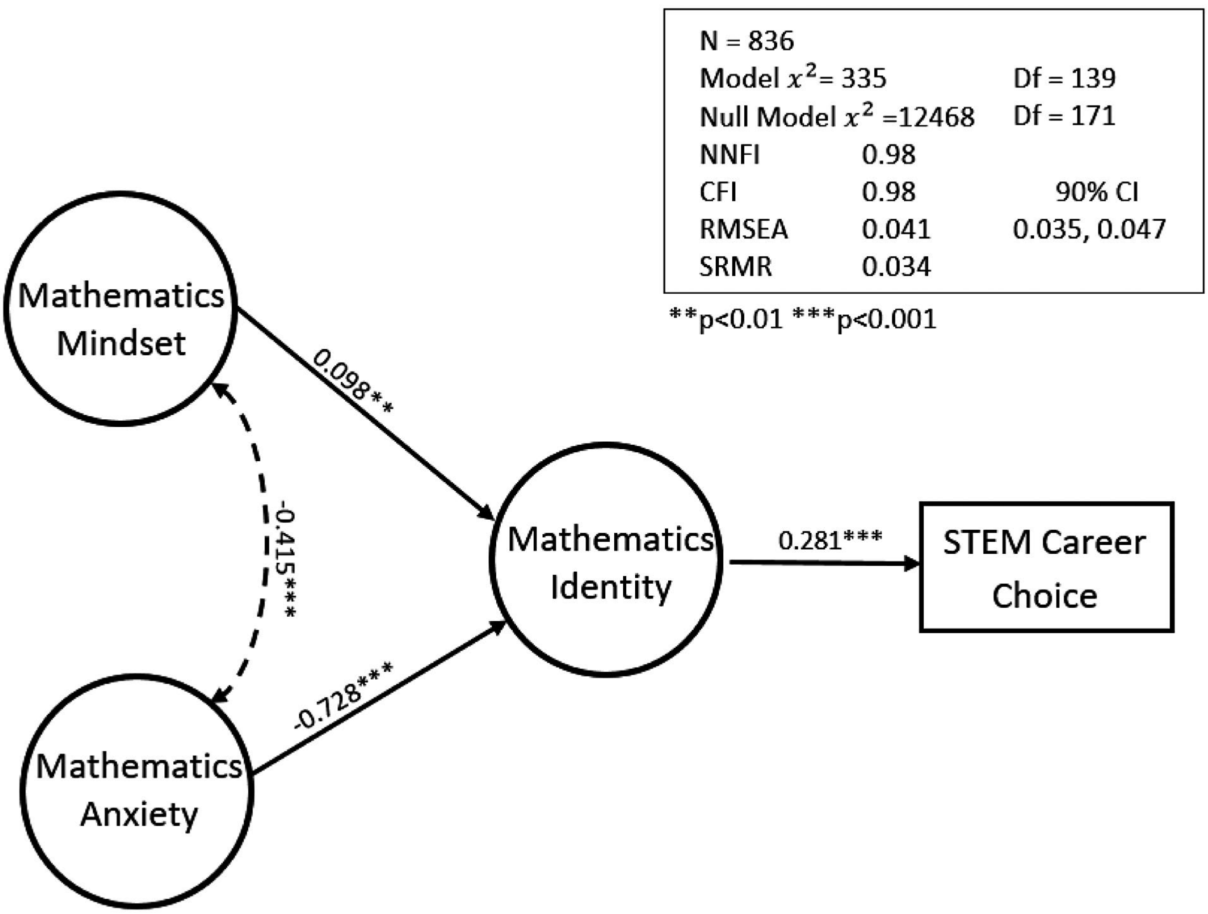

FIGURE 3 *SEM* results. C, confidence interval; Df, degrees of freedom; CFI, comparative fit index; NNFI, non-normed fit index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual

mediated through mathematics self-efficacy, which in turn would be partially mediated through mathematics identity in its impact on career interest. To the best of our knowledge, no previous literature has integrated these mathematics-related perceptions in one model to look into their intertwined relations in predicting STEM career interest. Our original model was tested with a sample of first-year undergraduate students at two public universities. The final model went through two rounds of modifications. In the first revised model, the direct paths from mathematics mindset and mathematics anxiety to STEM career choice were removed due to the nonsignificant predications. In the second revised model, mathematics self-efficacy was removed due to the multicollinearity issue, resulting in the final model that includes mathematics mindset, mathematics anxiety, mathematics identity, and STEM career choice. The findings of the revised model established the pathway from mathematics mindset and mathematics anxiety to STEM career choice through mathematics identity, which is a new finding.

Even though mathematic self-efficacy was removed in the final model to address the multicollinearity issue, the findings of our study confirmed previous research on the pathway from mathematics anxiety to mathematics self-efficacy, as well as from mathematics mindset to mathematics self-efficacy. The multicollinearity issue identified in the original model suggests that it should be re-tested in future research, as the issue could be with the particular data we collected (Schroeder, 1990). It is also possible that the mathematics self-efficacy measurement we selected for this study contributed to the multicollinearity issue, which is discussed in more depth in the Limitations and Future Directions subsection of this section.

Although we hypothesized a direct relationship between mathematics mindset and mathematics anxiety on STEM career choice, these paths were not significant. As evident in prior identity research in STEM education (Godwin et al., 2016; Jones et al., 2016), findings indicate that mathematics identity is a strong predictor of STEM career interest. When mathematics identity is included in the model, the direct effects of mathematics mindset (e.g., Burkley et al., 2010) on career interest observed in previous research were not revealed in the present study. However, this finding is consistent with other research, indicating that mindset relates indirectly to career aspirations, mediating by math value (Degol et al., 2018). Our findings indicate that having a malleable view of mathematics intelligence may increase undergraduate students' identification with mathematics. Boaler (2015) discusses this idea as it relates to how mathematics is taught in K-12 classrooms, stating that "students everywhere think that when they make a mistake it means that they are not a 'math person' or worse, that they are not smart" (p. 12). Individuals' experiences with mathematics that either support or hinder a growth mindset may contribute to their mathematics identity development, which in turn influences their STEM career interest.

Taken together, the study has one theoretical key finding to emphasize: that mathematics identity serves as a full mediator between mathematics mindset/mathematics anxiety and STEM career interest. This finding indicates the powerful mediating role of mathematics identity and their connection to career interest; there are complex and intertwined association among them.

Furthermore, our study has practical implications in STEM education as well. Given the shortage of individuals entering STEM fields in the United States, many educators are interested in ways to motivate more students to choose STEM fields. The results of our study seem to suggest that, at least at the beginning of one's college career, mathematics identity is a strong direct predictor and partially mediates effects of the other affective factors in the model on STEM career choice. Therefore, we believe that efforts to help college students strengthen their mathematics identity would be an effective means in motivating more college students to consider STEM careers. Moreover, when considering the subfactors of mathematics identity (interest and recognition), Cribbs et al. (2015) found that recognition by others, such as teachers and parents, had a stronger effect than interest on college students' mathematics identity. Therefore, we believe that college STEM faculty can play an important role in strengthening their students' mathematics identities through recognition and mentoring, which in turn could influence these students' STEM career interests. In other words, we recommend that STEM faculty who know students who they believe have an interest and motivation in the field, to personally encourage these students to continue in the field, as a way to help strengthen their STEM identities. This idea is supported by prior identity research indicating the important role that students' experiences on a university campus has on their perceptions of themselves as an engineer (Tonso, 2006). Also supporting this connection, Jones et al. (2016) found that undergraduate students' learning experiences in college, such as a sense of autonomy related to their learning environment and the usefulness of their learning experiences for their goals, predicted engineering identification. Likewise, research shows that faculty mentorship of female undergraduate students predicted their science identity and indirectly their persistence intentions (Hernandez et al., 2017).

Furthermore, our model shows that mathematics mindset has a direct positive influence, and mathematics anxiety has a direct negative influence, on mathematics identity. Therefore, utilizing evidence-based strategies for helping students develop a growth mindset and for reducing students' mathematics anxiety could also be useful in motivating more college students to consider STEM careers. For example, Dweck (2006) provided numerous recommendations on how educators can teach and encourage a growth mindset in their students. While many of these strategies have been predominantly studied among middle school students, Aronson et al. (2002) also found success with improving college students' mindsets. In addition, research has shown that developing a growth mindset often results in higher levels of achievement (Blackwell et al., 2007), especially among women and certain minorities (Aronson et al., 2002; Good et al., 2003) who tend to be underrepresented in STEM careers in the United States. Similarly, with regard to reducing learning anxiety, literature has identified effective instructional strategies, such as expressive writing and coping messages, which positively influenced mathematical learning through regulating learner anxiety (Huang & Mayer, 2016; Park et al., 2014; Sgoutas-Emch & Johnson, 1998). Therefore, utilizing such strategies with college students may not only improve students' mathematics identity but may also improve their achievement as well.

6.1 | Limitations and future directions

When considering our results, it is important to note that our data were collected from two universities in the United States, and the participants consisted mainly of Caucasian and female college students. Previous research has suggested an influence of gender in students' perceptions of mathematics anxiety (e.g., Ashcraft, 2002) as well as their career choice (e.g., Ellis et al., 2016). Future research should test our model with a balanced number of male and female participants or include gender as a moderating factor. Furthermore, there may be some concern regarding the representativeness of the participants of the study. As indicated previously, the percentage of the female participants in the sample (71%) did not match the percentage of female undergraduates at the two participating institutions (about 58% females in one university and 55% females in the other). Another related concern may be reflected in the fact that some STEM career goals (e.g., mathematician and physicist) in our survey were selected only by a few students. Therefore, the findings may be biased toward certain degrees, leading to questions regarding its generalizability to all college students. In addition, we focused on first-year college students because it is an important time when students are seriously considering their future career choices; however, we also recognize that the intertwined relations of the mathematics-related affective variables to STEM career interest may be different with younger students. Future research is needed to see if the results could be replicated with a more diverse sample.

In addition, the self-efficacy measure we used was adapted from the Confidence scale in the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). This instrument measures learners' self-confidence in mathematics learning in general (e.g., "I am sure that I can learn math"), rather than their confidence in specific mathematics tasks. In his original work, Bandura (1997) emphasized the task-specific nature of the self-efficacy construct. Other researchers have examined self-efficacy at a more general level. As Choi (2005, p. 198) explains:

> There has been a growing theoretical and empirical interest in redefining the structure of the construct. Several researchers speculate that self-efficacy may be structured hierarchically across multiple dimensions from more task-specific to more global domain-specific self-efficacy. Lent et al. (1997), for instance, posit that "academic self-efficacy beliefs are organized hierarchically such that, over time, students develop differentiated beliefs regarding their capabilities in larger academic domains (e.g., mathematics), as well as in more specific subtopics (e.g., calculus), skills, and situations within these broad domains" (p. 314).

One concern with more general self-efficacy measures is that they look similar to self-concept measures. Self-efficacy, however, is considered unidimensional in that it primarily involves one's cognitive judgment of their capabilities in comparison of their own past performances, while self-concept is considered multidimensional in that it includes both a cognitive and affective evaluation of one's attributes relative to others (Bong & Clark, 1999; Choi, 2005). At the operationalization level, the measures of these two constructs are sometimes not easy to tell apart. Furthermore, the more general measure of mathematics self-efficacy used in this study may have contributed to its high correlation with mathematics identity and the problem of multicollinearity. It may be helpful for future research to replicate this study using a task-specific mathematics self-efficacy measure to shed more light on the intertwined relations of mathematics mindset, mathematics anxiety, mathematics identity, and task-specific mathematics self-efficacy to STEM career choice.

Furthermore, we recognize that mindset, anxiety, and identity are not the only contributors to college students' future career choices. As mentioned previously, the original model including self-efficacy should be re-tested in future research. In addition, other factors, such as role models (Stout et al., 2011), parental influence (Ferry et al., 2000), and perceptions of STEM careers (Diekman et al., 2010), have been found to be influential in career choice decisions. Therefore, the role that these factors play, in collaboration with the four affective factors that we have studied, should also be explored by future research.

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