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Self-efficacy, mindfulness, and self-compassion as predictors of math anxiety in undergraduate students

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ABSTRACT

Many undergraduate students avoid mathematics classes due to math anxiety. This curtails options, particularly STEM majors where workers are needed and jobs are prevalent. This study aimed to investigate whether self-efficacy, mindfulness, and self-compassion predicted math anxiety. Participants of this study were undergraduate students ($N = 345$) from the Mathematics Department at a large Southeastern U.S. university. There was a significant difference in math anxiety scores between students pursuing STEM and non-STEM degrees. Non-STEM majors had higher scores on a measure of math anxiety. Hierarchical multiple regression results suggested that self-efficacy and self-compassion predicted math anxiety. There was a significant correlation, but not a predictive relationship, between mindfulness and math anxiety.

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KEYWORDS
Math anxiety; self-efficacy; mindfulness; self-compassion

1. Introduction

The need for employees in science, technology, engineering, and mathematics (STEM) fields continues to increase. Consequently, researchers are examining ways to help students to be more competent in mathematics to retain them in college and, particularly, in STEM majors (Czocher et al., 2020). Research suggests that it is important to recognize the emotional, as well as the cognitive, factors in mathematics achievement. Math anxiety is a critical emotional factor that affects performance, motivation, and interest in mathematics (Beilock & Maloney, 2015). To help students pursue mathematics and STEM careers, it is important to identify correlates of math anxiety (Samuel & Warner, 2021).

Most college majors include some mathematics requirement, and mathematics is an essential component for STEM majors. However, mathematics classes are often a barrier to many students' persistence in college, as well as to motivation or interest in pursuing STEM-related degrees. Moreover, math anxiety is associated with poorer performance in mathematics courses (Henslee & Klein, 2017) and may cause capable students to avoid these courses. Mathematics avoidance plays a role in avoidance of STEM-related occupations as well as overall mathematics achievement (Beilock & Maloney, 2015). It is

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important to increase understanding to address the negative emotions related to math anxiety and increase participation in post-secondary mathematics education as well as promote decisions to pursue STEM majors (Brunyé et al., 2013).

Most students have the cognitive ability to successfully perform mathematical tasks and understand mathematical concepts, but their fear and anxiety regarding the subject gets in the way (Tobias, 1991). Therefore, researchers agree that students would benefit from learning skills to help them manage and cope with their debilitating math anxiety (e.g. Tobias). There is a lack of current research on math anxiety at the university level (Andrews & Brown, 2015; Rozgonjuk et al., 2020). Increasing understanding of correlates of math anxiety may help to decrease this barrier to higher education and pursuit of STEM majors. Researchers are beginning to demonstrate that personality factors influence the development of math anxiety (Beilock & Maloney, 2015; Brunyé et al., 2013). The present study explored the personality aspects of self-efficacy, mindfulness, and self-compassion in relation to math anxiety in college students.

Research shows some differences between students who do and do not pursue STEM degrees. According to a report by the National Center for Education Statistics (NCES), students who chose to pursue STEM majors in the United States were generally younger or dependent students, took more mathematics classes in high school, had higher grade point averages and college entrance examination scores, were foreign students or those who spoke a language other than English as children, and came from more advantaged backgrounds than students pursuing non-STEM majors (NCES, 2009). Since there are varying definitions of STEM majors, here we should note that we are using the NSF STEM Classification of Instructional Programs to identify STEM majors, which includes the following categories: agricultural sciences, chemistry, computer science, engineering, environmental science, geosciences, life/biological sciences, mathematics, and physics/astronomy.

We have discussed how math anxiety may influence choice of a degree and persistence in STEM major. In the following sections, we examine math anxiety and the literature that connects self-efficacy, mindfulness, and self-compassion to this idea.

1.1. Math anxiety

The deleterious effect of math anxiety in college students is increasing. In a study of 180 college freshmen, Andrews and Brown (2015) found a negative relationship between math anxiety and standardized test scores and a negative relationship between math anxiety and final mathematics grade. However, cognitive researchers have demonstrated a complex relationship between negative emotions such as anxiety and academic performance. For instance, Wang et al. (2015) found an inverted U-shaped relationship between math anxiety and mathematics performance in motivated individuals; high and low levels of anxiety had a negative relationship with performance and moderate levels of math anxiety had a positive association with effective performance. In individuals with low mathematics motivation, the authors found a linear relationship between math anxiety and mathematics performance: the higher the math anxiety the lower the ability to perform mathematical problems.

Research in neuroscience demonstrates that attempts to regulate emotions, such as the worry and intrusive thoughts associated with math anxiety, usurp the resources in the neural networks needed for thinking, reasoning, working memory, and maintaining focused

attention (Beilock & Maloney, 2015; Brunyé et al., 2013). This suggests that students high in math anxiety direct their available cognitive and attentional resources on intrusive thoughts and worries rather than the executive functioning necessary for computing mathematical problems. Executive functioning includes cognitive ability, maintaining focused attention, planning, and working memory (Mind and Life Education Research Network [MLERN], 2012). Thus, when students experience math anxiety, they are attempting to do two things at once by focusing on their worry while trying to perform a mathematical task (Beilock & Maloney, 2015). Gaining skills to regulate emotions, such as mindfulness, self-compassion, and attitudes, such as self-efficacy, may free up mental resources needed to effectively direct attention during difficult mathematical problems (Brunyé et al., 2013).

1.2. Self-efficacy and math anxiety

Social cognitive theory (SCT) is a psychological model of learning and behaviour that suggests individuals are responsible for their thoughts, emotions, and behaviours (Bandura, 1997). Moreover, one's cognitions are the primary initiator of motivation and actions. Two core constructs of SCT are self-efficacy and outcome expectation. Self-efficacy refers to individuals' beliefs in their own ability to achieve success in a particular domain.

According to SCT (Bandura, 1997), self-efficacy and math anxiety have an inverse relationship (McMullan et al., 2012). Individuals with high levels of self-efficacy believe they have the capability to perform a behaviour or reach a desired goal. One's sense of self-efficacy influences the emotions and level of stress related to a task. A perceived lack of self-efficacy in learning and performance of mathematics can result in feelings of stress and anxiety (Bandura, 1993; Bandura et al., 1996). Thus, it is important for mathematics students to develop the ability to self-regulate their affective responses.

According to SCT, self-efficacy develops from four sources of influence (Bandura, 1997). The first and most influential source is one's mastery experience, or successful performance. Attainment of goals increases self-efficacy, while failures early on can undermine self-efficacy. The second basis for self-efficacy is through the observation of social role models, or vicarious experiences. The third source of self-efficacy is through positive verbal feedback from others while performing a difficult task, which is called social persuasion. The fourth source of self-efficacy arises from emotional/physiological states. Negative emotions, such as worry or anxiety, diminish self-efficacy and the ability to learn. On the other hand, positive states, such as calmness and confidence, enhance self-efficacy for academic learning and performance. The ability to manage anxiety when facing challenging situations improves self-efficacy, and reciprocally, improved self-efficacy helps to lower anxiety (Bandura). One's sense of self-efficacy influences the emotions and level of stress related to a task. Because a perceived lack of self-efficacy for learning and performance of mathematics can result in feelings of stress and anxiety (Bandura, 1993; Bandura et al., 1996) it is important for students to develop the ability to self-regulate their affective responses regarding mathematics.

Self-efficacy is related to persistence, goals, effort, and motivation (Bandura et al., 1996). Concomitantly, motivation and a positive attitude toward mathematics are related to self-efficacy for learning and performance (Czocher et al., 2020). Akin and Kurbanoglu (2011) examined the relationships among math anxiety, attitudes toward math, and self-efficacy in 372 university mathematics students. Through structural equation modelling, they found

that math anxiety was negatively related to positive attitudes and self-efficacy. The authors concluded that math anxiety was a consequence of lower perceived self-efficacy in mathematics. Moreover, negative cognitions and emotions regarding mathematics may lead to math anxiety. Thus, individuals' beliefs in their ability to achieve academically leads to success because it creates motivation and strategic thinking and reduces stress, anxiety, and worry regarding task performance (Bandura, 1993; Bandura et al., 1996).

1.3. Mindfulness and math anxiety

The ability to self-regulate emotions, improve executive functioning, and direct focused attention are important for academic success (MLERN, 2012; Shapiro et al., 2011). As previously mentioned, when students are focused on worry and anxiety it usurps the cognitive resources needed to focus on performing mathematics (Beilock & Maloney, 2015; Brunyé et al., 2013; Shayer, 2020). Mindfulness-related practices have been shown to reduce ruminative behaviours that interfere with self-regulatory and cognitive processes necessary for executive functioning (MLERN, 2012). Thus, increased levels of mindfulness may help to manage the debilitating effects of math anxiety by freeing up cognitive resources needed to focus attention effectively and to perform mathematical task (Shayer, 2020). Mindfulness can be defined as the intentional awareness of the present moment experience without judgement (Kabat-Zinn, 2003). Mindfulness helps to develop traditionally valued skills in academic achievement, such as concentration, memory, and focus, and it also cultivates skills associated with occupational success and wellbeing, such as emotion regulation and interpersonal skills (Shapiro et al., 2015). Moreover, mindfulness attenuates the experience of stress and fear (Tubbs et al., 2019).

The most widely used measure of mindfulness, the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2008) describes five components of mindfulness that include observe, describe, non-reactivity, non-judgement, and active awareness. *Observe* refers to noticing internal thoughts and feelings as well as external stimuli. *Describe* refers to the capacity to label experiences with words. *Non-reactivity* refers to the ability to refrain from overidentifying with or becoming overwhelmed by thoughts and feelings. *Non-judgement* refers to practicing acceptance and a non-evaluative attitude. *Acting with awareness* refers to the ability to pay attention to the present moment with directed focus.

An important aspect of mindfulness practice is decentering, which is the nonjudgmental observation of thoughts, feelings, and physical sensations (LaGue et al., 2020). Thus, mindfulness is often developed through formal meditation practice or yoga (MLERN, 2012). However, mindfulness can also be developed through informal practices, such as deep breathing, body scans, mindful activities, mindful walking, visualization, savouring, and observing detail (Kabat-Zinn, 1990/2005; Semple et al., 2010). The cultivation of mindfulness is associated with emotional, psychological, intellectual, and physical benefits (Shapiro et al., 2011).

Research supports the effectiveness of mindfulness practices in enhancing attention, focus, academic achievement, and emotion regulation in students. Shapiro et al. (2011) suggested that researchers should investigate mindfulness practices as a potential benefit to higher education. In an intervention study for math-anxious college students, Brunyé et al. (2013) found after a 15-min mindfulness-based breathing exercise aimed at addressing negative emotions related to math anxiety, participants demonstrated higher mathematics

scores than those who did not get the focused breathing intervention; although, low-anxiety students did even better. The authors suggested a more long-term intervention may demonstrate stronger results. This was evidenced by an intervention study that spanned two college semesters. Samuel and Warner (2021) found that after a mindfulness and growth mindset intervention embedded in a statistics class for two semesters, first year undergraduate students reported decreased math anxiety and increased mathematics self-efficacy. The authors suggested that mindfulness practice alleviates the overidentification with emotions such as worry, allowing the working memory to focus on the task at hand.

1.4. Self-compassion and math anxiety

Self-compassion has not yet been examined in the context of math anxiety; however, it is theoretically related to mindfulness. Self-compassion can be defined as the ability to generate kindness toward oneself to alleviate suffering, rather than avoid discomfort (Neff, 2003). Self-compassion is comprised of three components: self-kindness, common humanity, and mindfulness (Neff). *Self-kindness* refers to being caring and compassionate toward oneself, rather than critical and judgmental. *Common humanity* refers to the recognition that personal failings and suffering are part of the shared human experience rather than feeling isolated. The *mindfulness* component of self-compassion refers to recognition and awareness of one's positive or negative internal states without judgement or overidentification (Neff). Self-compassion can be cultivated (Shapiro et al., 2011) and is effective in regulating emotions (Neff et al., 2005).

Researchers have demonstrated an association between self-compassion and anxiety. Bergen-Cico and Cheon (2014) found that both mindfulness and self-compassion were associated with a reduction in anxiety, but the mediating effect of mindfulness was more robust. That is, increased mindfulness was associated with increased self-compassion, which in turn was associated with decreased anxiety. In a large population of clinical college students ($N = 1065$), Hayes et al. (2016) found that self-compassion scores were negatively related to depression ($r = -.67$, $p < .001$), generalized anxiety ($r = -.51$, $p < .001$), social anxiety ($r = -.57$, $p < .001$), and academic distress ($r = -.41$, $p < .001$). Manavipour and Saeedian (2016) found that self-compassion served as a coping mechanism because students higher in self-compassion were more likely to feel confident about improving future performance, thus potentially enhancing self-efficacy. Neff et al. (2005) found that self-compassion had a positive relationship with intrinsic motivation to learn and a negative relationship with anxiety. Finally, Akin (2008) replicated and supported the findings of Neff et al. (2005). Through structural equation modelling Akin demonstrated that self-compassion predicted intrinsic motivation to learn and was negatively associated with maladaptive avoidance attitudes regarding academic performance. Because research has demonstrated an inverse relationship between self-compassion and both anxiety and academic distress and has supported self-compassion as an effective coping skill, we were interested in investigating its potential relationship to math anxiety.

1.5. Research questions

In sum, research indicates that self-efficacy in mathematics students is associated with mathematics proficiency, motivation, and ultimately, persistence in STEM (Czocher et al.,

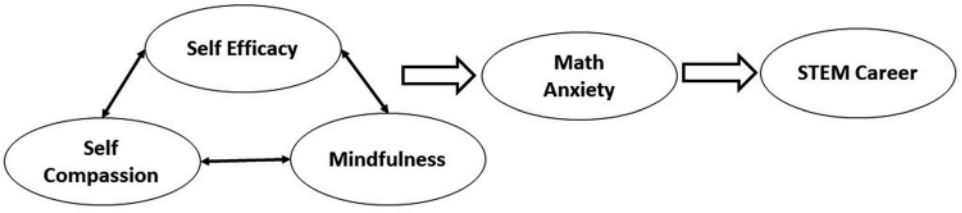

Figure 1. Hypothesized Relationships among Variables.

2020). Moreover, self-efficacy for learning and performance may ameliorate math anxiety (Bandura et al., 1996). In addition, there is burgeoning research that suggests mindfulness and the related construct of self-compassion may play an important role in improving cognitive functioning, focus, attention, and emotion regulation in students struggling with math anxiety. According to Beilock and Maloney (2015), 'success in mathematics requires not only knowledge of mathematical concepts but also the right mind-set' (p. 10). Therefore, the aim of this study was to investigate whether these constructs predict levels of math anxiety in mathematics students. An additional aim was to examine whether math anxiety scores differed between STEM and non-STEM majors in undergraduate mathematics students. Figure 1 illustrates our hypothesis that self-efficacy for learning and performance, mindfulness, and self-compassion together predict math anxiety, and that the level of math anxiety is associated with choosing a STEM-related career path.

Our research questions were as follows:

(1) Is there a difference in level of math anxiety between students who pursue STEM majors and those who pursue non-STEM majors?
(2) Do self-efficacy, mindfulness, and self-compassion predict math anxiety in a sample of mathematics students?

2. Methods

2.1. Participants

Upon approval from the Institutional Review Board (WVU #2107359853), participants were recruited from several different mathematics classes at West Virginia University, a large university in the southeastern U.S. After obtaining agreement from instructors, e-mails outlining the study and containing the survey link were sent to the students enrolled in the selected courses. Those who agreed to participate in the study completed the on-line surveys. Participants included a total of 345 undergraduate students enrolled in mathematics classes. The participants were fairly evenly distributed between self-identified female ($n = 171$; 49.6%) and male ($n = 144$; 41.7%) gender, with 8.7% ($n = 30$) participants indicating *other*, *prefer not to say*, or did not answer the question. The majority of participants indicated their ethnicity as White ($n = 269$; 78%). African American or Black participants made up 3% ($n = 10$) of the study population, 4% ($n = 14$) identified as Latino/Hispanic, 3.8% ($n = 13$) identified as Asian/Pacific Islander, 4% indicated other ($n = 14$; primarily multiple ethnicities), 2.3% preferred not to say ($n = 8$), and 4.9% ($n = 17$) did not answer the question. The majority of participants were in their freshman year of college ($n = 260$,

70.1%), 30 (8.7%) were in their sophomore year, 37 (10.7%) in their junior year, 14 (4.1%) in their senior year, and 22 (6.4%) did not answer the question. Most of the sample consisted of STEM majors ($n = 260$, 75.4%). There were 58 (16.8%) non-STEM majors, and 27 (7.8%) participants did not indicate their major. The majority of participants were from the U.S. ($n = 306$, 87%) and 20 (5.8%) participants did not answer the question. The remaining 7.2% of participants were from Africa ($n = 6$), the Middle East ($n = 8$), Asia ($n = 2$), Canada ($n = 1$), the UK ($n = 1$), and the Caribbean ($n = 1$).

2.2. Measures

2.2.1. The Abbreviated Mathematics Anxiety Rating Scale (AMARS; Alexander & Martray, 1989)

This survey is an abbreviated version of the MARS instrument to assess student anxiety levels during a semester. The AMARS consists of 25 items an includes three categories: Mathematics Exam Anxiety (15 items), Numerical Task Anxiety (five items), and Mathematics Course Anxiety (five items). The survey uses a 5-point Likert scale, ranging from 1 (*not at all*) to 5 (*very much*), to assess level of anxiety in specific situations. A sample item from the survey is '*Realizing you have to take a certain number of math classes to fulfill requirements*'. The survey has been validated on large populations (Alexander & Martray, 1989) and is based on the larger 84-item MARS instrument developed and validated by Richardson and Suinn (1972). This instrument shows high internal consistency and has been shown to reliably measure anxiety levels among students (Peterson et al., 2006). Cronbach's alpha for our sample was .96.

2.2.2. Self-Efficacy for Learning and Performance Subscale (SELPS) from the Motivated Strategies for Learning Questionnaire (MSLQ) for college students (Pintrich & De Groot, 1990)

The SELPS is an 8-item subscale from the 56-item MSLQ. The subscale uses a 7-point Likert-type scale, with responses ranging from 1 (*not at all true of me*) to 7 (*very true of me*). The subscale measures level of self-efficacy beliefs and expected successful performance on specific tasks. An example of an item on the instrument is '*I'm confident I can do an excellent job on the assignments and tests in this course*'. The total score range of the SELPS is 8–56. Studies have confirmed adequate internal consistency. The Cronbach's alpha for the current study was .96.

2.2.3. Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006)

The FFMQ is a 39-item instrument that uses a 5-point Likert-type scale, with responses ranging from 1 (*never or very rarely true*) to 5 (*very often or always true*). The instrument includes five subscales that assess the five facets of mindfulness, including observing (OBS), describing (D), acting with awareness (AA), non-judging of inner experience (NJ), and non-reactivity to inner experience (NR). An example of an item from the OBS subscale is '*I pay attention to sensations, such as the wind in my hair or the sun on my face*'. A sample item from the D subscale is '*I'm good at finding words to describe my feelings*'. A sample item from the AA subscale is '*I rush through activities without being really attentive to them*'. A sample item from the NJ subscale is '*I think some of my emotions are bad or inappropriate and I shouldn't feel them*'. A sample item from the NR subscale is '*I perceive my feelings and*

emotions without having to react to them'. The total score range of the FFMQ is 39–195. Higher scores indicate higher level of mindfulness. Nineteen of the questions are reverse scored. Studies have confirmed adequate internal consistency of the FFMQ, with Cronbach's alphas for the five subscales ranging from 0.67 to 0.93 (Park et al., 2013; Williams et al., 2014). Cronbach's alpha for the present study was .83.

2.2.4. Self-Compassion Scale-Short Form (SCS-SF; Raes et al., 2011)

The SCS-SF is a 12-item measure shortened from the 26-item self-compassion scale (SCS; Neff, 2003). The SCS-SF measures three facets of self-compassion, each consisting of two subscales: (a) self-kindness versus self-judgment, (b) common humanity versus isolation, and (c) mindfulness versus over-identification. An example of a self-kindness item is '*When I'm going through a very hard time, I give myself the caring and tenderness I need*'. An example of a common humanity item is '*I try to see my failings as part of the human condition*'. An example of a mindfulness item is '*When something upsets me I try to keep my emotions in balance*'. The measure uses a Likert-type scale ranging from 1 (*almost never*) to 5 (*almost always*). Higher scores indicate higher levels of self-compassion. Half of the items are reverse scored. Confirmatory factor analysis demonstrated that the shortened SCS has the same higher-order factor structure as the original full scale with a 'general' higher-order self-compassion factor and six second-order factors corresponding to the six facets of self-compassion. The correlation between the total score of the long and short form was excellent, $r = .97$ (Raes et al., 2011). Cronbach's alpha for the present sample was .83.

3. Data analysis and procedure

Data were analyzed using IBM SPSS Statistics 26 to conduct the descriptive analyses, *t*-test, and hierarchical multiple regression. Power analyses were calculated using GPower 3.1 (Faul et al., 2007). It was determined that the minimum sample size for a one-tailed *t*-test with a medium effect size was 64. The minimum sample size for multiple regression with a medium effect size, $\alpha = .05$, power of .90, and three predictors was 41. Our total sample size was much higher at 345.

The order of variables entered into the hierarchical multiple regression was based on empirical support (Pallant, 2020). To control for demographic factors, we entered type of major and gender in block 1. Because of the difference we found in levels of math anxiety between STEM and non-STEM majors, we included it along with gender as a covariate. Gender was included as a covariate because researchers recognize that gender accounts for disparities in STEM-related majors and careers; women are less likely to pursue STEM majors (Czocher et al., 2020). According to the literature, women tend to hold implicit negative attitudes toward mathematics compared to men as a result of the stereotypical belief that men are better in mathematics than women, along with a lack of a sense of belonging in STEM-related academics (Czocher et al., 2020; Good et al., 2012). Moreover, extant literature suggests gender differences in mathematics self-efficacy (Ramos Salazar, 2018; Tariq et al., 2013), math anxiety (Ganley & Vasilyeva, 2014), and self-compassion (Ramos Salazar, 2018; Yarnell et al., 2015). Given the empirical evidence of the influence of gender in relation to many of the variables in the present study, we chose to control for potential gender effects in the analyses.

In block 2, we added self-efficacy due to its strong support regarding mathematics engagement and achievement in the literature (Samuel & Warner, 2021). We then entered mindfulness in block 3 as there is considerable empirical support of mindfulness in education (Shapiro et al., 2011). Finally, we added self-compassion in block 4 because there is no literature related to math anxiety and very little literature related to mathematics achievement; however, literature does suggest that self-compassion is associated with learning goals (Neff et al., 2005) and anxiety (Hayes et al., 2016). Additionally, in a quick search of the library database, we found 670 peer-reviewed articles on mindfulness and education compared with 54 on self-compassion and education.

4. Results

4.1. Research question 1

Research question 1 explores the difference in level of math anxiety between students who pursue STEM majors and those who pursue non-STEM majors. Preliminary analyses determined assumptions for t-tests were met. The sample was large enough to accommodate non-normal distribution of data (Pallant, 2020); however, histograms revealed data were normally distributed. Non-significant Levene's test confirmed homogeneity of variance ($F = .11, p = .74$).

An independent samples t-test was conducted to compare the math anxiety scores for students pursuing STEM majors ($M = 68.35, SD = 19.22$) and those pursuing non-STEM majors ($M = 75.93, SD = 20.45; t(303) = -2.65, p = .008$). The magnitude of the difference was small ($\eta^2 = .023$). Students pursuing non-STEM majors endorsed higher levels of math anxiety than those pursuing STEM majors.

4.2. Research question 2

Research question 2 examines whether self-efficacy, mindfulness, and self-compassion predict math anxiety in our sample of mathematics students. Preliminary analyses were conducted for the multiple regression to ensure no violation of assumptions of normality, linearity, multicollinearity, and homoscedasticity. Normality and linearity were verified through visual inspection of scatterplot (relatively rectangular shape; all less than 3 standard deviations) and P–P Plot (diagonals). The correlation matrix (Table 1) indicated correlations between all variables were below .7 indicating multicollinearity was not a problem. In addition, tolerance values were above .10 and VIF values were below 10. There was independence of residuals as assessed by Durbin-Watson statistic of 1.976. Homoscedasticity was determined by visual inspection of a plot of studentized residuals verses unstandardized predicted values. There was no undue influence of any case; the maximum value for Cook's Distance was .146.

Hierarchical multiple regression was conducted to assess the ability of self-efficacy, mindfulness, and self-compassion to predict level of math anxiety. Gender and type of major were entered at Step 1, explaining 3.2% of the variance. Self-efficacy was entered at Step 2, explaining an additional 22% of the variance. Mindfulness was entered at Step 3, explaining an additional .9% of the variance. Self-compassion was entered at Step 4,

Table 1. Correlations for study variables.

Variable	1	2	3	4	5	6
1. Math anxiety	–	.15**	.10*	−.48***	−.22***	−.31***
2. Major	.15**	–	.04	−.11*	.02	−.04
3. Gender	.10*	.04	–	.05	−.04	−.09
4. Self-efficacy	−.48***	−.11*	.05	–	.27***	.32***
5. Mindfulness	−.22***	.02	−.04	.27***	–	.47***
6. Self-compassion	−.31***	−.04	−.09	.32***	.47***	–

Note: Major refers to STEM vs. Non-STEM.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 2. Multiple regression results for math anxiety.

		95% CI for *B*					
Variable	*B*	*LL*	*UL*	*SE B*	*β*	R^2	ΔR^2
Final model						.28	.27
Constant	104.57***	90.33	118.81	7.24***			
STEM/Non-STEM	4.91	−.14	9.95	2.56	.096		
Gender	3.50*	.172	6.83	1.70	.103*		
Self-efficacy	−.79***	−.99	−.59	.10	−.415***		
Mindfulness	−.04	−.13	.06	.05	−.041		
Self-compassion	−.38*	−.67	−.09	.15	−.147*		

Note: CI = confidence interval; *LL* = lower limit; *UL* = upper limit.
*$p < .05$. ***$p < .001$.

explaining an additional 1.6%. The final model explained 26.6% of the variance in level of math anxiety. Results are presented in Table 2.

5. Discussion

The aim of the current study was to examine self-efficacy, mindfulness, and self-compassion as predictors of math anxiety as well as to determine if there is a difference in level of math anxiety between students pursuing STEM and non-STEM majors. Prior research has not investigated self-compassion as a predictor of math anxiety, and researchers are just beginning to empirically explore the relationship between mindfulness and math anxiety. The findings from this study serve to advance future scholarship in STEM education and may help educators to tailor instruction or interventions to ameliorate math anxiety.

Our first research question explored whether there was a difference in levels of math anxiety between those students pursuing STEM majors and those who were not. Our results indicated that non-STEM majors had statistically significant higher math anxiety scores than the STEM majors, which supports the literature suggesting math anxiety is a deterrent to pursuing STEM majors and occupations (e.g. Beilock & Maloney, 2015; Brunyé et al., 2013). Our results contradict those of a recent study that examined levels of math anxiety in STEM and social sciences students (Rozgonjuk et al., 2020). The authors found that type of major did not predict levels of math anxiety in their sample. The researchers had expected that the social sciences students would endorse higher math anxiety than the STEM students. A possible explanation is that our non-STEM sample included majors other than social sciences, such as history, finance, fashion, and education. Our findings

may have been different if all the non-STEM majors in our sample were social sciences students. While our result does not prove causality, it does show an association between math anxiety and pursuit of STEM majors. It is possible that students with higher levels of math anxiety chose to pursue non-STEM majors.

Our second research question explored whether self-efficacy, mindfulness, and self-compassion predicted math anxiety. While the final model was significant, not all predictors significantly added to the variance. Self-efficacy was the strongest predictor of math anxiety in the model; as self-efficacy increased, math anxiety decreased. This makes sense because students who feel confident in their academic abilities, will not need to worry as much about their performance in mathematics. This finding is in line with previous research by Akin and Kurbanoglu (2011) that found a negative correlation between math anxiety and self-efficacy in 372 university students ($r = -.49$, $p < .01$). McMullan et al. (2012) also found a strong negative correlation between math anxiety and mathematics self-efficacy ($r = -.63$, $p < .001$). Other studies have primarily investigated self-efficacy as a predictor of mathematics motivation (e.g. Ramos Salazar, 2018); the present study adds to the nascent literature regarding self-efficacy as a predictor of math anxiety in post-secondary mathematics students.

Although there was a statistically significant negative correlation between mindfulness and math anxiety in the present study, mindfulness was not a significant predictor of math anxiety and accounted for a very small portion of the variance in the final model. This finding is contrary to the literature on mindfulness and math-anxiety. Recent qualitative research has demonstrated support for mindfulness as an intervention to alleviate math anxiety. For example, high school students reported reduced math anxiety after completing twelve 45-min mindfulness-based cognitive therapy sessions over 6 weeks (LaGue et al., 2020). In a case study of college students, participants reported reduced math anxiety after completing six *Mindful Math* sessions (Shayer, 2020). Quantitative research also supports an inverse relationship between mindfulness and anxiety. Sherwood et al. (2020) found that mindfulness predicted negative beliefs about worry, in a negative direction, in undergraduate students ($N = 446$). In addition, negative beliefs about worry mediated the relationship between mindfulness and anxiety. However, the authors examined four of the five mindfulness facets individually. They did not include the *describe* subscale in their study due to evidence it may be associated more with depression than anxiety. The *non-reactivity*, *non-judgement*, and *acting with awareness* facets were associated with decreased negative beliefs about worry and that the *observe* subscale was not a significant predictor of negative beliefs about worry. This suggests that perhaps only some of the facets of mindfulness are reliable predictors of anxiety and related cognitions. In the current study, because mindfulness was not a significant predictor of math anxiety and contributed very little to the variance in math anxiety scores, we did not conduct post hoc analyses on the FFMQ subscales. However, future research should continue to explore the subscales in relation to math anxiety.

An exciting and novel finding of our study is the support of self-compassion as a significant predictor of math anxiety in the negative direction; higher self-compassion predicted lower math anxiety. These results add to the burgeoning research on the promising potential of self-compassion in relation to math anxiety and mathematics education. Neff et al. (2005) and Akin (2008) conducted the only two studies to date on self-compassion and learning goal orientations. Using structural equation modelling, Akin (2008) examined all

six self-compassion subscales in relation to learning goals in 646 undergraduate students. Overall, self-compassion positively predicted learning (mastery) goals and negatively predicted performance (grades-focused) goals. These findings support the results of Neff et al. (2005), who found that self-compassion had a positive association with a learning goal orientation and negative associations with performance approach and avoidance goal orientations. The relationship between self-compassion and academic goal orientation was mediated by the lower fear of failure and greater perceived competence in those higher in self-compassion.

The above research helps to explain the results of the current study. Students with higher levels of self-compassion may feel more academically confident, have mastery instead of performance goal orientations, and less fear of failure. Students with a learning goal orientation are motivated by curiosity and a desire to learn and master subjects, and they understand that failure is part of the learning process (Neff et al., 2005). Individuals with self-compassion meet their failures with kindness and understanding, rather than overidentifying with the failure, thus are not as afraid to make mistakes (Akin, 2008) which in turn reduces anxiety about performance.

5.1. Limitations and future research

Several limitations should be considered when interpreting these results. First, participants in this study were from one university, the population was fairly homogeneous, and students self-selected to participate. Therefore, there are threats to external validity, and generalizability to other populations is uncertain. Future research should attempt to replicate the study with heterogeneous populations to address this gap. Second, data were missing across instruments and participants, most likely due to testing fatigue. Future research may examine the shorter versions of the instruments. Third, as this was a cross-sectional study, causation cannot be determined. The next step is to investigate these variables in an experimental or quasi-experimental design, comparing an intervention with a control group, which is currently under way. Future research should incorporate longitudinal studies with larger sample sizes to help determine causal relationships. In addition, our final model accounted for just under 30% of the variance in math anxiety. Future research should explore other potential correlates of math anxiety.

5.2. Implications for educators

Mathematics educators realize that students have many barriers to being successful in mathematics, and many of these barriers do not involve the mathematics content but seem to stem from something deeper in the emotional or psychological realm. For years, interventions for skill remediation or to encourage success in mathematics courses focused on academic content modifications and more active learning techniques (Apkarian et al., 2021). These changes in curriculum have met with mixed success with a portion of the students still not responding or grasping key ideas. Although students' deficient mathematical backgrounds or depth of understanding make up portions of the problem, other aspects of their inability to achieve success, although evident, often go unaddressed. Many students will openly admit 'I am just not good at math' or 'I hate math'. Further, many students who struggle in mathematics classes will intimate stories about a former teacher who had

an effect on their self-efficacy by telling them they were hopeless or were not able to learn mathematics.

This study seeks to consider the aspects of these emotional and psychological barriers to mathematical success. Most mathematics educators at the college-level do not have a professional teaching certification. While college professors are usually required to have an advanced degree in their discipline, they do not usually have any training in learning theory or educational psychology. Most of these college-level educators will readily admit that math anxiety exists, but many may think it comes from students who refuse to study hard enough and thus are not prepared for the test or for class. Many of these educators never stop to determine the underlying cause for the anxiety and how it might be helped. Some educators try to overcome student math anxiety by being more personable and less intimidating, but many do not see helping students to overcome math anxiety as part of their job. Kelly et al. (2020) recently linked math anxiety with 'instructor's misbehaviors' (i.e. antagonism, lectures). Their paper predicted that instructor misbehaviors decrease students' perceived immediacy, thereby increasing students' math anxiety.

The current study seeks to draw attention to some factors that affect math anxiety so that educators can begin to determine how to implement interventions that increase self-efficacy, mindfulness, and self-compassion and in turn lower math anxiety. Each student comes from a unique background, set of beliefs, and experiences, so what will work for one student might not have any effect on another. However, in considering some of the different factors that in some way affect math anxiety, educators can begin to incorporate different methods and techniques that may have positive effects on one or more of the factors. Publishers like Cengage are starting to see the usefulness of including these ideas in their materials for students. For example, they have recently developed Math Mindset Modules (Cengage, 2021), that include many of these ideas. The authors have considered these factors that affect math anxiety and are currently testing interventions in College Algebra classes at a large university.

6. Conclusion

This study provides empirical support for the possibility that math anxiety is a factor in avoidance of pursuing STEM majors in college or STEM occupations. In addition, our results indicate that self-efficacy, self-compassion, and gender are predictors of math anxiety. The results also point to the possibility that aspects of mindfulness may predict math anxiety. These findings provide insight into some of the correlates of math anxiety. Understanding these factors can provide educators with valuable direction in addressing math anxiety in students.

Disclosure statement

No potential conflict of interest was reported by the authors.

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