International Journal of Science and Mathematics Education
https://doi.org/10.1007/s10763-023-10416-4

Undergraduate Students' Math Anxiety: the Role of Mindset, Achievement Goals, and Parents

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Received: 1 February 2023 / Accepted: 24 August 2023

Abstract
The undergraduate college years are a critical time when students are beginning to think seriously about their career interests, and it is critical that students have a positive outlook for their mathematical learning if they are going to pursue math-related STEM majors. The current research with 748 undergraduate math students found that the more they endorsed a fixed mindset, the more they were likely to experience math anxiety, a relationship partially explained by their adoption of mastery-avoidance and performance-avoidance goals. Furthermore, the degree of this mediation effect did not differ for men and women. While women were not more likely to hold a fixed mindset for their math intelligence, they did report higher scores for math anxiety in comparison to men. In addition, if students felt that when they were growing up, their parents were uncomfortable helping them with math homework, it also led to students' math anxiety, and this was partially explained by influencing students' fixed mindset beliefs about their math intelligence.

Keywords Goals · Math anxiety · Mindset · Parents · STEM

Student Interest in Math-Related STEM Fields

Encouraging students' interest in the subjects of science, technology, engineering, and mathematics (STEM) continues to draw the interest of educators and educational researchers. As such, there are ongoing efforts to examine the factors that shape students' engagement in STEM and the potential for new approaches and strategies for encouraging students to pursue STEM coursework and careers

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Published online: 07 September 2023

(Diekman et al., 2017; LaForce, Noble & Blackwell, 2017; Muenks et al., 2020; Murphy et al., 2019). Wang and Degol (2013) point out that US employers report a shortage of skilled workers entering the STEM workforce and that concerns remain about the number of women willing to pursue STEM careers, and thus it is essential that we better understand the factors that influence educational and career choices. University and post-compulsory participation in STEM education, and interest in STEM careers, are also of ongoing international concern (Kier et al., 2014; Regan & DeWitt, 2015; Ritz & Fan, 2015). Researchers worldwide are increasingly examining the affective factors related to adolescent STEM learning, attitudes, and interest (Staus et al., 2020).

Self-efficacy for mathematical learning, competency beliefs, intrinsic motivation, and task value are all likely predictors of STEM interest, subject selection, college major, and career aspirations (Blotnicky et al., 2018; Guo, Parker, Marsh & Morin, 2015; Guo, Marsh, Parker, Morin & Dicke, 2017; LaForce et al., 2017; Murphy et al., 2019; Usher & Pajares, 2008; Wang & Degol, 2013). Math anxiety can also have effects on STEM courses and career choices (Ahmed, 2018; Ashcraft, 2002; Huang et al., 2019; Luttenberger et al., 2018). Math anxiety is a fear or apprehension of math which can increase math avoidance and hinder math competence, and those with math anxiety tend to avoid math and college majors and career paths that heavily depend on math skills (Ashcraft, 2002). There is some evidence to suggest parents do play a role in shaping their children's math anxiety, and they may even transfer their own math anxiety to their children (Batchelor et al., 2017; Luttenberger et al., 2018).

In this paper, we distinguish math anxiety from math anguish. Math anguish, which many learners experience at first, may be considered part of the natural process of learning mathematics and may lead to some frustration while learning math. Some learners may experience more apprehension or anguish when learning math than others which may impact their dispositions toward the subject. According to Reys et al. (2015), teachers need to encourage their students to be persistent in their questioning so that all learning is made clear to them and to prevent long-term math anxiety or ongoing confusion or gaps. In addition, teachers need to check for dispositions toward math, as pointed out in Standard #10 of the National Council of Teachers of Mathematics (NCTM, 1989). While teachers may instinctively try to avoid the undesirable effects of anxiety in learning, as educators, we need to show we value the learning process and encourage students' understanding that some frustration is evident in the learning of mathematics.

Therefore, this study examines how students' mindsets, or beliefs about the malleability of their mathematic ability, or the resultant achievement goals they adopt, may influence some students to experience math anxiety. Wang and Degol (2013) suggest that motivational beliefs, which are informed by aptitudes in math and science, competence beliefs, interest, and beliefs about the malleability of intellectual ability, undoubtedly play a role in students' decisions to pursue STEM fields of study. This investigation also investigates how parents' own discomfort with math may shape their children's mindset and math anxiety.

Mindset, Achievement Goals, and Mathematics

Dweck (2006) points out the importance of encouraging adaptive motivational mindsets for learning, and she highlights a growth mindset, or thinking about intelligence and one's ability as something to be developed and cultivated through one's efforts. However, some think of intelligence as something finite, a fixed mindset, where you are either good at something or you are not. The two mindsets are also associated with different goals that students adopt for their learning. The prevailing belief is that those with growth mindsets are more likely to pursue mastery goals with a focus on learning and individual improvement. Individuals with fixed mindsets are more likely to be concerned with performance goals and how they will be judged. However, the predominant achievement goal model categorizes four achievement goals, with mastery and performance goals being further distinguished by either approach or avoidance motivation (Elliot & McGregor, 2001; Elliot & Murayama, 2008). Math students espousing mastery-approach goals are challenge-seeking and pursue opportunities to extend their learning, whereas those driven by performance-approach goals will endeavor to do better because they want to compare favorably in comparison to others. In contrast, students with mastery-avoidance goals seek to avoid misunderstandings or failure, while those with performance-avoidance goals want to avoid being judged unfavorably by others. Approach goals, particularly the mastery approach, may be linked with math students' self-efficacy, self-regulated learning, and study strategies, while both avoidance goals have either uncertain or negative links to students' self-efficacy and self-regulated learning in math (Bong, 2009; Huang, 2016).

Relationship to Math Anxiety

Some research indicates it may be that students' mindsets, and the resultant achievement goals they adopt, influence some students to experience math anxiety. Students with a growth mindset may be more likely to value math and pursue STEM careers, whereas those with fixed mindsets may be more likely to see success and failure as tied to ability, engage in avoidance strategies including withdrawal or disengagement, and experience anxiety (Degol et al., 2018). Muenks et al. (2020) reported that when undergraduate students perceive their professors in STEM-related disciplines to endorse a fixed mindset, students experience more psychological vulnerability such as a lower sense of belonging, evaluative concerns, and anxiety, which in turn leads to a lower class attendance, less class engagement, lower grades, an intent to drop out, and less interest in STEM at the end of the semester. In particular, students' evaluative concerns included self-doubt, feeling like a fraud or imposter, and being afraid of doing or saying the wrong thing which is conceptually reminiscent of the performance-avoidance goal. These findings make sense given that those with fixed mindsets are concerned with how they will be judged and not on how to improve, become afraid of challenges, feel labeled by their mistakes, and can become overwhelmed by feelings of failure (Dweck, 2006).

However, some research has suggested that female learners may report more psychological vulnerability. A fixed mindset, combined with the cultural stereotype that women have less math ability than men, can undermine women's sense of belonging in math, lead to self-defeating thoughts about their own math ability, and influence their desire to pursue math in the future (Dweck, 2007, 2008; Good et al., 2012). It has even been suggested that females may be more likely to hold a fixed mindset in their science and mathematical learning (Chen & Pajares, 2010; Murphy et al., 2019). Therefore, it is important to further examine gender differences in both rates of math anxiety and fixed mindsets for mathematical learning.

Some researchers have examined the relationship between math anxiety and goals using the 2 × 2 model of achievement goals. Results with secondary and college-age students enrolled in math courses have shown both avoidance goals to be clear predictors of anxiety, while mastery-approach goals may predict lower negative affect and anxiety (Luo, Hogan, Tan, Kaur, Ng & Chan, 2014; Sideridis, 2008). Our own past research suggests that considering the achievement goals of undergraduate elementary education students may increase our ability to predict math anxiety beyond that afforded by just looking at their reported self-efficacy alone (Gonzalez-DeHass, Furner, Vasquez-Colina & Morris, 2017). For these students, both the avoidance goals, and not the mastery-approach goals, were predictive of math anxiety in their mathematics pedagogy coursework. Therefore, it appears that avoidance goals may be particularly important in predicting math anxiety. Because these goals follow from students' overall views of intelligence, it is likely that a fixed mindset impacts how much math anxiety they experience, and it may partly do so by influencing the goals they adopt.

Parents' Discomfort with Math

Yeager and Dweck (2012) have discussed that explaining difficulty in terms of fixed traits erodes students' resilience and leads them to feel discouraged when they face challenges. What students need is a growth mindset that frames academically demanding learning tasks as things they can overcome with effort, new strategies, help from others, and patience. Yeager and Dweck point out that this messaging can come from parents as well as teachers. It may be that if parents are uncomfortable helping their children with math homework, it can lead to students' experiencing math anxiety, possibly by encouraging a fixed mindset theory of intelligence. Despite limited empirical research, there is some evidence to suggest parents do play a role in shaping their children's math anxiety (Batchelor et al., 2017). Both teachers' and parents' attitudes toward children's math ability can facilitate the development of math anxiety, and parents may transfer their own math anxiety to their kids (Luttenberger, Wimmer & Paechter, 2018).

Haimovitz and Dweck (2016) pose the possibility that parents' failure mindsets may be most visible to children and more pivotal in shaping their beliefs. Because if parents see failure as incapacitating and feel anxious when they see indications their children are failing, their anxiety and concerns about their children's poor performance can become apparent in their interactions with their children. Their results showed that children's perceptions of their parents' failure mindsets then predicted their children's mindsets. Their children, in turn, come to see intelligence as fixed rather than malleable and that they cannot develop their intelligence. The findings suggest that this is because these parents react to their children's failures by focusing more on their children's ability or performance than on their learning.

Research conducted by Moorman and Pomerantz (2010) indicates that when mothers hold a fixed mindset, they use more "unconstructive involvement" with their children, characterized by control and an emphasis on getting answers right rather than actual learning. The authors noted that such involvement may be harmful to their children's academic and emotional functioning. However, there is insufficient research on parent involvement in specific subjects like math in influencing students' motivation (Silinskas & Kikas, 2019) and how parents may shape their math anxiety (Batchelor et al., 2017). Therefore, it would be of interest to examine how parents' discomfort helping with homework as students were growing up may impact students' fixed mindsets for mathematical learning and their math anxiety.

The Present Study

The undergraduate years are a critical time when students are beginning to think seriously about their career interests and the appropriate college majors that will serve as a path to realizing those interests. While there may be various factors at work, of most interest to the present study is whether students' mindsets or the achievement goals they adopt contribute to whether they experience anxiety about their mathematical learning. It is likely that a fixed mindset impacts how much math anxiety students experience, and it may partly do so by influencing the goals they adopt. Students with fixed mindsets may be more likely to see success and failure as tied to ability and engage in avoidance or withdrawal as a coping strategy (Degol et al., 2018), and the two avoidance goals have been shown to be more likely to predict math anxiety (Bong, 2009; Gonzalez-DeHass et al., 2017; Sideridis, 2008).

Understanding the nature of this impact is particularly important for female students, who may be more vulnerable or susceptible to the fixed mindset's negative effect on their mathematical learning. This includes not only understanding whether women report more math anxiety, but also whether they are more likely to hold a fixed mindset for math intelligence or if the mediational pathway between mindset and math anxiety via avoidance goals is different for men and women. In addition, there is insufficient research on how parents help with math homework, and any discomfort they experience while doing so, might influence their children's mindset for math or their math anxiety. To the best of our knowledge, no studies have examined these angles. If achievement goals prove an influential mediating variable, they may serve as an effective avenue to encourage students to have a more positive motivational outlook for math-related STEM learning. This is because the goals students hold can be changed within classrooms to help improve students' learning outcomes (Ames, 1992; Urdan, 1997). Therefore, our study examines the following research questions:

1. Are the relationships between students' fixed mindsets of intelligence and math anxiety mediated by their avoidance goals?
2. Do women report higher math anxiety than men?
3. Are women more likely to report a fixed mindset of their math intelligence than men?
4. Does the mediation pathway between mindset and math anxiety differ between men and women?
5. Does parental discomfort influence students' math anxiety directly as well as via students' fixed mindset of intelligence?

Method

Participants

Participants were 748 students enrolled in multiple sections of undergraduate math courses at a large southeastern university in the USA that include College Algebra, Precalculus Algebra, Trigonometry, Precalculus Algebra and Trigonometry, Methods of Calculus, and Introductory Statistics. The sample ethnic breakdown is provided in Table 1. All participants were 18 years or older. The researchers used pairwise deletion to handle missing values. There were only a few cases of missing data (no response).

Instruments

An online survey was distributed and stored electronically through Google.docs, and it was composed of three instruments: the Achievement Goal Questionnaire-Revised, the Abbreviated Math Anxiety Scale, and the Theories about Math Intelligence Scale. The survey also contained one final section of demographic questions referring to students' age, gender, grade, and ethnicity. This section also included one question asking whether students felt that when they were growing up, their parents were uncomfortable or unsure in helping them with math homework or encouraged them to seek help elsewhere. Participants responded "A great deal," "Some," or "Not at all."

Achievement Goal Questionnaire-Revised (AGQ-R)

The AGQ-R, developed by Elliot and Murayama (2008), includes twelve Likert-type items designed to better measure students' reported achievement goals on four goal dimensions: mastery-approach, performance-approach, mastery-avoidance, and performance-avoidance. Participants responded on a scale of whether the statement was very true (7) or not at all true (1) of them regarding their learning in the math course. Each goal subscale has three items; a sample item in the mastery-approach scale is "My aim is to completely master the material presented in the class." A sample item in the mastery-avoidance scale is "I am striving to avoid an incomplete

Table 1 Student demographics

Variable	Number
Ethnicity	
Caucasian (non-Hispanic)	327
African American	138
Hispanic/Latino	152
Middle Eastern/Arab American	58
Asian/Pacific Islander	45
Native American/Alaskan Native	8
Other	6
No response	14
Gender	
Female	377
Male	350
No response	21
Age	
18–20 years old	541
26–30	29
31–35	10
36–40	4
41 above	6
No response	18
Class standing	
Freshmen	344
Sophomore	209
Junior	128
Senior	46
Graduate	9
No response	12

understanding of the course material." A sample item in the performance-approach scale is "I am striving to do well compared to other students." A sample item in the performance-avoidance scale is "My aim is to avoid doing worse than other students." Internal reliability for the scales in the present study was comparable to those reported in the instrument's original validation study and yielded coefficient alphas as follows: mastery-approach (α =. 87), performance-approach (α =. 86), mastery-avoidance (α =.80), and performance-avoidance (α =. 82).

Abbreviated Math Anxiety Scale (AMAS)

The AMAS provides a measure of college students' math anxiety (Hopko et al., 2003). The creators used items from the full-scale MARS (Richardson & Suinn, 1972) and from the MARS-R (Plake & Parker, 1982) to develop the AMAS using an undergraduate student population. The primary purpose is to create an abbreviated version of the other lengthier MARS versions. The AMAS has nine items measuring levels of math anxiety in individuals' math class experiences including during math assessments, numerical tasks, math courses, and math homework. Items on the AMAS were responded to using a 5-point Likert-type scale, ranging from 1 (low anxiety) to 5 (high anxiety), with the total score representing a summation of the nine items. Because this measure captures math anxiety across classes and not specifically in the math class participants were enrolled in, it is best seen as a trait measure of math anxiety. Sample items include "Having to use the tables in the back of a math book" and "Taking an examination in a math course." Comparable to the instrument's validation study, internal reliability for the AMAS yielded a coefficient alpha of α =.90.

Theories About Math Intelligence Scale (TMIS)

The TMIS measures students' mindsets toward mathematics and is a modified version of Dweck's Implicit Theories of Intelligence Scale (Dweck, 2000). There are four items where participants responded on a scale of whether they strongly agree (6) to strongly disagree (1) with statements reflecting their beliefs about their mindset, or theories about math intelligence as either a fixed trait or as an ability capable of being developed. Sample items include "To be honest, you can't really change how intelligent you are in math" and "You can learn new things, but you can't really change your basic math intelligence." Therefore, higher scores represent students who have more of a fixed mindset. Lower scores will be indicative of a growth mindset. Internal reliability for the TMIS scale in the present study yielded a coefficient alpha of $\alpha = .94$.

Procedures

After securing institutional review board (IRB) approval for research involving human subjects, we sent course instructors the recruitment information to share in their classes. Participants in lower-division mathematics courses were invited to participate in the online survey. The Mathematics Department Chair assisted in obtaining the instructors and lower division mathematics courses to use for the study as outlined in the IRB. Researchers did not collect data on response rates; however, the Mathematics Department instructors were asked to send two reminders via their online learning management system as well as an email to their students to about participating in the study. The instructor directed participants to a link for the online consent form and survey. Individual instructors were given the option to provide students with an extra credit opportunity for those students completing the survey, and recruitment materials included two scripts, depending on whether the instructor was willing to extend extra credit for participation. If extra credit was offered, an alternative one-page writing assignment to the survey was offered to students. However, all participants were assured that there was no penalty if they chose not to participate, that completion of the survey had no relation to their course grade, and that they were free to withdraw from the study at any time. The survey did not display any student identifiers, and all data were reported in aggregate.

Data Analysis

To answer the first research question, a simple mediation analysis was done, parsing the effect of fixed mindset on math anxiety into two parts; that part that is direct from fixed mindset to math anxiety, and that part that is indirect, working its way through each avoidance goal. Furthermore, the mediation effect herein was tested in two ways, with Sobel's parametric test, and with bootstrapping via Andrew Hayes' SPSS macro (Hayes, 2013). A 95% CI was used with 10,000 bootstrap samples. It is important to note that due to the large sample size, small effects were significant. This applied to all mediation tests. To answer our second and third research questions, independent-sample *t*-tests were conducted to compare the math anxiety, and likelihood to report a fixed mindset of their math intelligence, for men and women. Mediation analyses were also used for the last two research questions on whether the mediation pathway between mindset and math anxiety differs between men and women, as well as whether parental discomfort influences students' math anxiety directly as well as via students' fixed mindset of intelligence.

Results

There were many significant correlations between the study variables, albeit some were small, as reported in Table 2. A fixed mindset had significant positive associations with math anxiety and the performance-approach, mastery-avoidance, and performance-avoidance goals. Math anxiety was also significantly and positively related to parents' discomfort to help with math.

Our first research question investigated if the relationships between fixed mindset and math anxiety were mediated by their avoidance goals. The mediation effect (.0141) for the mastery-avoidance goal was significant, with a 95% bootstrap CI of [.0007, .0356]. However, most of the total effect was direct (~98%), with only about 2% being attributable to the indirect path. An almost identical result was obtained using the performance-avoidance goal as the mediator, with a significant mediation effect, .1064, 95% CI of [.0006, .0407], but with only a small part (~2%) of the total effect "traveling" through the indirect path with the rest (~98%) being a direct effect of the fixed mindset of math intelligence on math anxiety (Table 3) (Figs. 1 and 2).

The next set of research questions focused on women participants. Our second research question asked if women were more likely to have higher math anxiety than men in our study. An independent-sample *t*-test was conducted to compare math anxiety for men and women. There was a significant difference in the scores for men's (M = 25.17, SD = 9.52) and women's (M = 27.41, SD = 8.74) math anxiety; $t(725) = -3.31$, p = 0.001, d =.25 with women tending to report higher scores of math anxiety. Our third question examined whether women were also more likely to report a fixed mindset of their math intelligence than males.

Table 2 Means, standard deviations, and simple correlations with pairwise deletion (*N* below)

	M	SD	1	2	3	4	5	6	7	8
1. Mastery approach	18.02	3.81	--							
2. Mastery avoidance	15.59	5.26	.50** (748)	--						
3. Performance approach	17.88	4	.73** (748)	.46** (748)	--					
4. Performance avoidance	17.08	4.81	.55** (748)	.68** (748)	.71** (748)	--				
5. Abbreviated math anxiety	25.97	9.68	.14** (748)	.13** (748)	.18** (748)	.16** (748)	--			
6. Parent's discomfort to help	1.89	.75	-.07 (731)	-.04 (731)	-.03 (731)	.002 (731)	.20** (731)	--		
7. Mindset	12.34	6.53	.032 (748)	.11** (748)	.11** (748)	.09* (748)	.45** (748)	.15** (731)	--	
8. Gender	--	--	.03 (727)	.006 (727)	.08* (727)	.04 (727)	.12** (727)	.04 (721)	.04 (727)	--

High scores on the mindset variable indicate a fixed mindset

*$p < .05$, **$p < .01$.

Table 3 Mediation test for each *X*, mediator, and outcome

Number	*X*	Mediator	Outcome	Effect	Bootstrap 95% CI	Sobel *z*	*p*	Indirect %	Direct %
748	Mindset	Mastery avoidance	Math anxiety	.014*	[.001, .036]	1.920	.060	2.1	97.9
748	Mindset	Performance avoidance	Math anxiety	.016*	[.001, .041]	2.030	.042	2.4	97.6
731	Parents' discomfort	Math intelligence	Math anxiety	.707*	[.337, 1.114]	3.874	< .001	28.2	71.8

CI, bootstrapped confidence interval

*Arises from the bootstrap 95% CI result. *$p < .05$

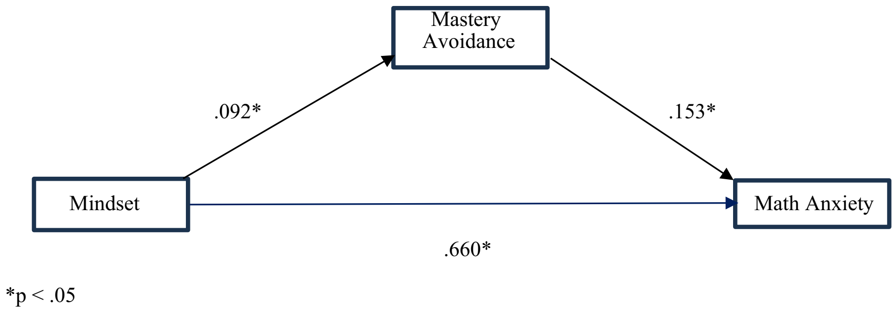

Fig. 1 Regression coefficients for mediation of the relationship between mindset and math anxiety by mastery avoidance. *$p < .05$

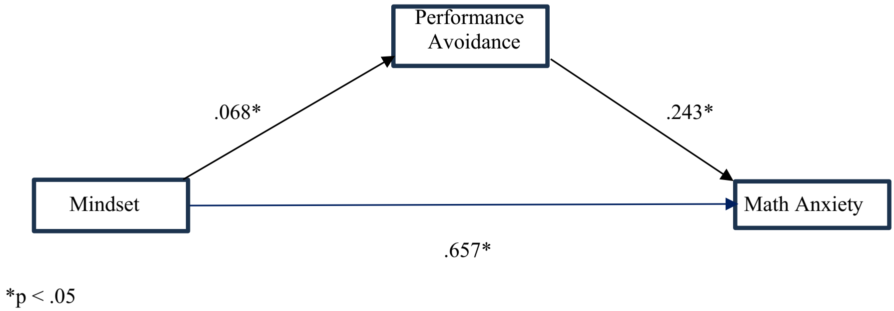

Fig. 2 Regression coefficients for mediation of the relationship between mindset and math anxiety by performance-avoidance. *$p < .05$

An independent-sample *t*-test was conducted to compare the mindset of men and women. The difference in means between men ($M = 12.22$, $SD = 6.65$) and women ($M = 12.77$, $SD = 6.13$) was not significant, $t(725) = 1.16$, $p > .05$. However, women were more likely to report higher scores for math anxiety in comparison to men (see Table 2).

Regarding the fourth research question, whether mediation effects previously considered in research question 1 (if the relationships between fixed mindset and math anxiety were mediated by their avoidance goals) were equivalent for males and females, moderated mediation tests were accomplished with bootstrapping. Both mediation effects for the mastery avoidance goal (−.0085, $SE = .0092$) and for the performance-avoidance goal (−.0023, $SE = .0068$) were not significant given their CI, [-.0308, .0046] and [−.0197, .0092] respectively. Both contained zero, and thus were not significant. These mediation effects did not depend on gender.

Our fifth research question investigated whether the relationship between parents' discomfort with helping with math homework and math anxiety is mediated by students' fixed mindsets. The results show the indirect effect, .7073, is significant, 95% CI [.3369, 1.1141], and it may also be considered substantial.

About 28% of the effect of parents' discomfort operates by impacting students' fixed mindset of intelligence, which then impacts math anxiety, with about 72% directly impacting math anxiety (Fig. 3).

Discussion

The current study makes several unique contributions to the literature. First, to the best of our knowledge, no studies to date have examined how the fixed mindset might predict undergraduate college students' math anxiety via the mastery- and performance-avoidance goals students adopt. Secondly, this study also examined how parents' own discomfort with math may influence their children's fixed mindset for mathematical learning and the math anxiety they experience during learning. Students' mindsets, or beliefs about the malleability of their mathematic ability, and achievement goals may help to explain why some students' experience math anxiety and others have a more positive motivational outlook to pursue math-related STEM majors and careers at a time early in college when they are making key decisions regarding math-related STEM courses and majors.

Mindset, Goals, and Math Anxiety

Because achievement goals follow students' overall views of intelligence, we examined whether the relationships between students' fixed mindsets for their math intelligence and math anxiety are mediated by their avoidance goals. Mastery-avoidant goals are linked to avoiding the possibility of being faced with one's inability to master math tasks, and performance-avoidant goals are linked to avoiding poor evaluations of their math performance by others. Our results indicated that the more students endorsed a fixed mindset the more they were likely to experience math anxiety, a relationship partially explained by their adoption of mastery-avoidance and performance-avoidance goals.

The direct impact that a fixed mindset had on students' math anxiety was very apparent. This makes sense considering what we know about the fixed mindset.

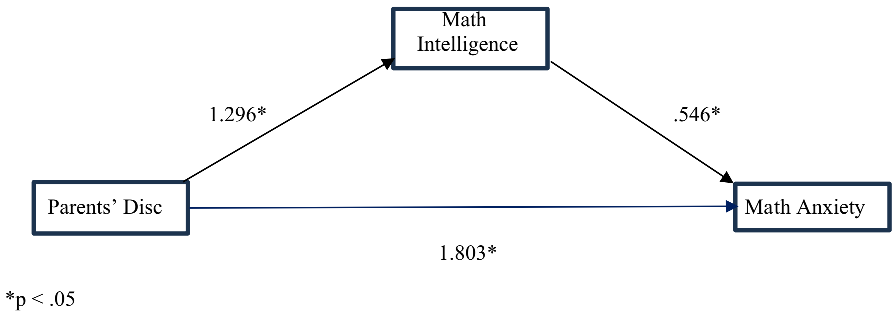

Fig. 3 Regression coefficients for mediation of the relationship between parents' discomfort and math anxiety by math intelligence. *$p < .05$

The fixed mindset does not hold the belief that intelligence is malleable and can be improved through effort, hard work, and new strategies. Consequently, the fixed mindset creates a drive to prove oneself rather than improve, and hide deficiencies rather than overcome them, and this can lead to a place of distress and paralysis in the face of failure for students (Dweck, 2006). Students with a fixed mindset may be more likely to see success and failure as tied to ability, engage in avoidance strategies including withdrawal or disengagement, and experience anxiety (Degol et al., 2018). When undergraduate students perceive their professors in STEM-related disciplines to endorse a fixed mindset, students experience more psychological vulnerability such as a lower sense of belonging, anxiety, and evaluative concerns like self-doubt, feeling like a fraud or imposter, and being afraid of doing or saying the wrong thing (Muenks et al., 2020).

There were also significant indirect effects through students' avoidance goals that align with other research examining how goals have been linked to students' math anxiety. Furthermore, these mediation effects did not differ based on gender. Research with secondary and college-age students enrolled in math courses has shown both avoidance goals to be predictors of anxiety, particularly mastery-avoidant goals (Luo et al., 2014; Sideridis, 2008). In addition, taking into consideration the avoidance goals of undergraduate elementary education students may increase our ability to predict math anxiety over that afforded by their level of self-efficacy alone (Gonzalez-DeHass et al., 2017). Adopting either avoidance goal while learning mathematics may leave students particularly susceptible to math anxiety. Findings from the current study add to these findings by looking at how these avoidance goals may serve as important mediators because goals follow from students' broader views of intelligence.

While our results revealed that women were not more likely to hold a fixed mindset for their math intelligence, and the mediation effects between mindset and math anxiety did not differ by gender, women did report higher scores for math anxiety in comparison to men. Math anxiety is of pronounced concern for female students who may be more susceptible to the stereotype that women have less math ability than men, and this can lead to self-defeating beliefs about their own ability (Dweck, 2007; Good et al., 2012). Math anxiety is negatively correlated with self-efficacy across ages (Bong, 2009; Kesici & Erdogan, 2009; Pajares & Kranzler, 1995). Therefore, these stereotypes may play a role whereby women perceive themselves to be less skilled in math, and self-efficacy clearly predicts interest and persistence in these fields including choices in STEM coursework and careers (Diekman et al., 2017; Murphy et al. (2019). Teaching implications designed to minimize the fixed mindset, and the potentially maladaptive goal orientations they are associated with, may be especially important in encouraging women in STEM who may be less willing to pursue STEM majors and careers.

Parents' Discomfort with Math and Students' Mindset and Math Anxiety

Our results also indicated that if students felt that when they were growing up, their parents were uncomfortable or unsure about helping them with math homework, or encouraged them to seek help elsewhere, it led to students' math anxiety, and this was partially explained by influencing students' fixed mindset belief about their math intelligence such that they see their mathematical ability as something finite, and you are either good at it or you are not. So, it could be that when students see their parents struggle with their own discomfort and insecurities with math, for some to the point of it being insurmountable and they must turn to others for help, it can lead to their own fixed mindset and math anxiety. This builds on existing research that suggests parents play a role in shaping their children's math anxiety (Batchelor et al., 2017; Luttenberger et al., 2018).

These current findings also build on research beginning to explore how parents may influence students' mindset for their mathematical learning. Haimovitz and Dweck (2016) have suggested that parents' failure mindsets may be more visible than their growth mindsets, and their anxiety and concerns can become apparent to their children. Therefore, parents who believe failure is debilitating have children who develop a fixed mindset. Our study extends the scope of parents' impact on the mathematical learning of undergraduate students by finding that when students witness their parents reacting with discomfort, hesitancy, or sending their kids elsewhere to seek help, it also influences students' fixed mindset and math anxiety at a time when they begin making key decisions regarding math-related STEM courses and majors.

Implications

Targeting students' growth mindsets and achievement goals for learning is a feasible and primary implication of these findings. The growth mindset and adoption of mastery goals play an important role in students' STEM participation (Murphy et al., 2019). Educators can structure classroom environments to minimize potentially maladaptive goal orientations, particularly those associated with avoidance goals, and make adaptive goal orientations more salient (Gonzalez-DeHass et al., 2017). Our findings indicate that the goals students adopt are significant mediators between their mindsets and important mathematical learning behaviors. Encouraging students' mastery-approach goals (in place of avoidance goals) is one viable avenue to affect change. Students' goal adoption can be shaped within classrooms to help improve students' learning (Ames, 1992; Urdan, 1997). Therefore, math educators in higher education can engage in strategies to encourage students' mastery approach to learning.

Overall, educators can use strategies that draw on Ames' (1992) work on learning environments in relation to achievement goal theory and implications from Epstein's (1987) TARGET model of ideal family structures for children's academic motivation (Gonzalez-DeHass, 2020). These include designing meaningful and authentic homework tasks; encouraging student choice, planning, and goal setting; praising process-focused and effortful learning; and framing mistakes as opportunities for growth. Overall, math educators can convey to students that they understand and value the process of learning—applying effort, trying many strategies, and persevering through difficulty. This is of pronounced concern for female students who may be more vulnerable to fixed mindsets and cultural stereotypes that women have less math ability than men (Dweck, 2007; Good et al., 2012). Intervention should challenge stereotypes and nurture growth mindsets relative to STEM ability, where effort is highlighted over innate math ability (Diekman et al., 2019). This best occurs in a supportive learning environment that highlights bi-directional communication and fosters rapport between students and the teacher, where both acknowledge the fundamental understanding that initial failures are a springboard for ongoing learning.

Reys et al. (2015) emphasize that math teachers encourage students to keep pushing the teacher until the learning is made clear to them while also helping them appreciate that the process of learning math can be confusing, frustrating, and some partial misunderstanding as the process of learning math as being normal. This paper does not fully explore the natural anguish associated with learning math and instead looks at math anxiety as a long-term disposition developed toward the subject over time. The problem of distress in learning math has always been the edict of the times in mathematics teaching. Many young people by the time they have reached college-level courses have already formed particular dispositions toward mathematics based on many years of K-12 schooling.

In general, math anxiety appears as an unwanted effect to be minimized by understanding the pedagogical structures and contexts that may diminish the long-term math anxiety that leads learners to avoid math-related STEM majors and careers. Important teaching strategies that ease the math learning process include the learning tasks that are assigned, how students are evaluated, and the nature of the supportive feedback teachers offer to students. The teacher plays a critical role that impacts the students and how they feel toward the subject long-term from year to year. Dispositions are often formed over years of taking mathematics classes with different teachers. These are the pedagogical and contextual aspects we should seek to better understand that impact the overall disposition toward math of a learner developed over time.

Math educators can also enlist parental assistance to assist students in creating concrete plans for meeting their goals, use praise effectively, and remind students to view their mistakes as opportunities for continued growth (Dweck, 2006). This reinforces the importance of communicating more effective ways to react to their children's setbacks that avoid reinforcing failure mindsets (Haimovitz & Dweck, 2016). As Haimovitz and Dweck (2016) noted, "an intervention targeting parents' failure mindsets could teach parents how failure can be beneficial, and how to react to their children's setbacks so as to maintain their children's motivation and learning" (p. 867). This type of intervention could lead children to adopt a growth mindset, perseverance, and "grit," if failures are interpreted as informative and motivating rather than disheartening. Students need to know that struggling with hard tasks is more important than gliding to success on easy ones (Dweck, 2010). For Yeager and Dweck (2012), a central task for parents and educators is encouraging students' mindset that represents challenges as things that they can overcome with time and effort, new strategies, help from others, and patience. Therefore, educators and parents can help redirect students to see that their ability can be developed with effort (a growth mindset) and emphasize mastery-approach goals, so they are more resilient when working on demanding math tasks.

Limitations and Future Directions

There are study limitations which restrict the generalization of findings. First, although common in the achievement goal literature, this study used self-reported measures. However, participants' answers were anonymous, and existing validated instruments were used. In addition, while this study is based on a relatively large sample, it used a sample of convenience, so we offered a detailed description of our participant sample. Finally, the survey we used only offered student participants two gender options. Future work may want to expand the categories offered to reflect non-binary gender identities. Overall, we encourage future researchers to examine larger and more diverse samples nationally and internationally. Our results support continued investigation into the factors of students' mindset and goals, as well as parent involvement practices surrounding homework during K-12 years, as influential to undergraduate students' motivation for their mathematical learning and willingness to pursue math-related STEM fields.

Declarations

Ethical Approval and Consent to Participate The study reported in this paper was conducted under the approval of the Human Subjects Institutional Review Board (IRB) Committee of Florida Atlantic University [327467-3]. Informed consent was obtained from the participants included in the study.

References

Ahmed, W. (2018). Developmental trajectories of math anxiety during adolescence: Associations with STEM career choice. *Journal of Adolescence, 67*, 158–166. https://doi.org/10.1016/j.adolescence.2018.06.010

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84*(3), 261–271. https://doi.org/10.1037/0022-0663.84.3.261

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185. https://doi.org/10.1111/1467-8721.00196

Batchelor, S., Gilmore, C., & Inglis, M. (2017). Parents' and children's mathematics anxiety. In U. X. Eligio (Ed.), *Understanding emotions in mathematical thinking and learning* (pp. 315–336). Elsevier. https://doi.org/10.1016/B978-0-12-802218-4.00012-1

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education, 5*(1), 1–15. https://doi.org/10.1186/s40594-018-0118-3

Bong, M. (2009). Age-related differences in achievement goal differentiation. *Journal of Educational Psychology, 101*(4), 879–896. https://doi.org/10.1037/a0015945

Chen, J. A., & Pajares, F. (2010). Implicit theories of ability of grade 6 science students: Relation to epistemological beliefs and academic motivation and achievement in science. *Contemporary Educational Psychology, 35*, 75–87. https://doi.org/10.1016/j.cedpsych.2009.10.003

Degol, J. L., Wang, M. T., & Zhang, Y. (2018). Do growth mindsets in math benefit females? Identifying pathways between gender, mindset, and motivation. *Journal of Youth and Adolescence, 47*, 976–990. https://doi.org/10.1007/s10964-017-0739-8

Diekman, A. B., Clark, E. K., & Belanger, A. L. (2019). Finding common ground: Synthesizing divergent theoretical views to promote women's STEM pursuits. *Social Issues and Policy Review, 13*(1), 182–210. https://doi.org/10.1111/sipr.12052

Diekman, A. B., Steinberg, M., Brown, E. R., Belanger, A. L., & Clark, E. K. (2017). A goal congruity model of role entry, engagement, and exit: Understanding communal goal processes in STEM gender gaps. *Personality and Social Psychology Review, 21*(2), 142–175. https://doi.org/10.1177/1088868316642141

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*. Taylor & Francis.

Dweck, C. S. (2006). *Mindset: The new psychology of success.* Random House.

Dweck, C. (2007). Is math a gift? Beliefs that put females at risk. In S. J. Ceci & W. M. Williams (Eds.), *Why aren't more women in science? Top researchers debate the evidence* (pp. 47–55). APA Press.

Dweck, C. S. (2008). *Mindsets and math/science achievement*. Retrieved January 14, 2022 from http://www.growthmindsetmaths.com/uploads/2/3/7/7/23776169/mindset_and_math_science_achievement_-_nov_2013.pdf

Dweck, C. S. (2010). Can we make students smarter? *Education Canada, 49*(4), 56–61.

Elliot, A. J., & McGregor, H. A. (2001). A 2 x 2 achievement goal framework. *Journal of Personality and Social Psychology, 80*(3), 501–519.

Elliot, A. J., & Murayama, K. (2008). One the measurement of achievement goals: Critique, illustration, and application. *Journal of Educational Psychology, 100*(3), 613–628.

Epstein, J. L. (1987). *TARGET: An examination of parallel school and family structures that promote student motivation and achievement* (Report No. 6). Center for Research on Elementary and Middle Schools Report. Retrieved from ERIC http://ezproxy.fau.edu/login?url=http://resolver.ebscohost.com.ezproxy.fau.edu/openurl?url=https://search-proquest-com.ezproxy.fau.edu/docview/63152909?accountid=10902

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology, 102*(4), 700–717. https://doi.org/10.1037/a0026659

Gonzalez-DeHass, A. R. (2020). *Parent involvement for motivated learners: Encouraging self-directed and resilient students*. Routledge.

Gonzalez-DeHass, A. R., Furner, J. M., Vasquez-Colina, M. & Morris, J. D. (2017). Pre-service elementary teachers' achievement goals and their relationship to their math anxiety.*Learning and Individual Differences, 60*, 40–45. https://doi.org/10.1016/j.lindif.2017.10.002

Guo, J., Parker, P. D., Marsh, H. W. & Morin, A. J. S. (2015). Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective. *Developmental Psychology, 51*(8), 1163–1176. https://doi.org/10.1037/a0039440

Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S. & Dicke, T. (2017). Extending expectancy-value theory predictions of achievement and aspirations in science: Dimensional comparison processes and expectancy-by-value interactions. *Learning and Instruction, 49*, 81–91. https://doi.org/10.1016/j.learninstruc.2016.12.007

Haimovitz, K., & Dweck, C. S. (2016). Corrigendum: What predicts children's fixed and growth intelligence mind-sets not their parents views of intelligence but their parents' views of failure. *Psychological Science, 27*, 859–869. https://doi.org/10.1177/0956797617697952

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford Press.

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The abbreviated math anxiety scale (AMAS) construction, validity, and reliability. *Assessment, 10*(2), 178–182. https://doi.org/10.1177/1073191103010002008

Huang, C. (2016). Achievement goals and self-efficacy: A meta-analysis. *Educational Research Review, 19*, 119–137. https://doi.org/10.1016/j.edurev.2016.07.002

Huang, X., Zhang, J., & Hudson, L. (2019). Impact of math self-efficacy, math anxiety, and growth mindset on math and science career interest for middle school students: The gender moderating effect. *European Journal of Psychology of Education, 34*, 621–640. https://doi.org/10.1007/s10212-018-0403-z

Hurst, M., & Cordes, S. (2017). When being good at math is not enough: How students' beliefs about the nature of mathematics impact decisions to pursue optional math education. In U. X. Eligio (Ed.), *Understanding emotions in mathematical thinking and learning* (pp. 221–241). Elsevier. https://doi.org/10.1016/B978-0-12-802218-4.00008-X

Kesici, S., & Erdogan, A. (2009). Predicting college students' mathematics anxiety by motivational beliefs and self-regulated learning strategies. *College Student Journal, 43*(2), 631–642.

Kier, M. W., Blancard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the STEM career interest survey. *Research in Science Education, 44*, 461–481. https://doi.org/10.1007/s11165-013-9389-3

LaForce, M., Noble, E. & Blackwell, C. (2017). Problem-based learning (PBL) and student interest in STEM careers: The roles of motivation and ability beliefs. *Education Sciences, 7*, 92. https://doi.org/10.3390/educsci7040092

Luo, W., Hogan, D., Tan, L. S., Kaur, B., Ng P. T. & Chan, M. (2014). Self-construal and students' math self-concept, anxiety and achievement: An examination of achievement goals as mediators. *Asian Journal of Social Psychology, 17*, 184–195. https://doi.org/10.1111/ajsp.12058

Luttenberger, S., Wimmer, S. & Paechter, M. (2018). Spotlight on math anxiety. *Psychology Research and Behavior Management, 11*, 311–322. https://doi.org/10.2147/PRBM.S14

Moorman, E. A., & Pomerantz, E. M. (2010). Ability mindsets influence the quality of mothers' involvement in children's learning: An experimental investigation. *Developmental Psychology, 46*(5), 1354–1362. https://doi.org/10.1037/a0020376

Muenks, K., Canning, E. A., LaCosse, J., Green, D. J., Zirkel, S., Garcia, J. A., & Murphy, M. C. (2020). Does my professor think my ability can change? Students' perceptions of their STEM professors' mindset beliefs predict their psychological vulnerability, engagement, and performance in class. *Journal of Experimental Psychology: General, 149*(11), 2119–2144. https://doi.org/10.1037/xge0000763

Murphy, S., MacDonald, A., Wang, C. A., & Danaia, L. (2019). Towards an understanding of STEM engagement: A review of the literature on motivation and academic emotions. *Canadian Journal of Science and Mathematics and Technology Education, 19*, 304–320. https://doi.org/10.1007/s42330-019-00054-w

National Council of Teachers of Mathematics (NCTM) (1989). *Curriculum and evaluation standards for school mathematics.* National Council of Teachers of Mathematics.

Pajares, F., & Kranzler, J. (1995). Self-efficacy beliefs and general mental ability in mathematical problem-solving. *Contemporary Educational Psychology, 20*, 426–443. https://doi.org/10.1006/ceps.1995.1029

Plake, B. S. & Parker, C. S. (1982). The development and validation of a revised version of the mathematics anxiety rating scale. *Educational and Psychological Measurement, 42,* 551–557. https://doi.org/10.1177/001316448204200218

Regan, E., & DeWitt, J. (2015). Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature. In E. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education*. Springer. https://doi.org/10.1007/978-94-007-7793-4_5

Reys, R. E., Lindquist, M. M., Lambdin, D. V., Smith, N. L., & Suydam, M. N. (2015). *Helping children learn mathematics* (11th ed.). John Wiley & Sons Publishing, Inc.

Richardson, F. C. & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology, 19*, 551–554. https://doi.org/10.1037/h0033456

Ritz, J. M., & Fan, S. C. (2015). STEM and technology education: international state-of-the-art. *International Journal of Technology and Design Education, 25*, 429–451. https://doi.org/10.1007/s10798-014-9290-z

Sideridis, G. D. (2008). The regulation of affect, anxiety, and stressful arousal from adopting mastery-avoidance goal orientations. *Stress and Health, 24*, 55–69. https://doi.org/10.1002/smi.1160

Silinskas, G. & Kikas, E. (2019). Parental involvement in math homework: Links to children's performance and motivation. *Scandinavian Journal of Educational Research, 63*(1), 17–37. https://doi.org/10.1080/00313831.2017.1324901

Staus, N. L., Lesseig, K., Lamb, R., Falk, J., & Dierking, L. (2020). Validation of a measure of STEM interest for adolescents. *International Journal of Science and Mathematics Education, 18*, 279–293. https://doi.org/10.1007/s10763-019-09970-7

Urdan, T. C. (1997). Achievement goal theory: Past results, future directions. In M. Maehr & P. R. Pintrich (Eds.), *Advances in Motivation and Achievement* (Vol. 10, pp. 99–141). JAI Press.

Usher, E. L., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research, 78*(4), 751–796. https://doi.org/10.3102/0034654308321456

Wang, M., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy-value perspective to understand individual and gender differences in STEM fields. *Developmental Review, 33*, 304–340. https://doi.org/10.1016/j.dr.2013.08.001

Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist, 47*(4), 302–314. https://doi.org/10.1080/00461520.2012.722805