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Abstract

Math anxiety has become an alarming social justice concern, as it results in negative academic consequences, contributes to disinterest and lack of persistence in STEM programs for underrepresented students, and limits their opportunities in STEM careers. According to research, this fear of math occurs long before students begin working on math problems. When high-math anxious students encounter math situations, anticipation anxiety consumes working memory capacity, inhibits learning, and causes them to severely underperform on mathematical tasks. However, very few studies have been conducted to embed psychological interventions in the classroom in an effort to mitigate both anticipation and execution anxiety. Findings from preliminary research suggest that a combined mindfulness and growth mindset intervention, designed to address both anticipation and execution anxiety, was effective in reducing math anxiety in students in a semester-long statistics course. The current research, a replication of the successful pilot study, investigated the generalizability of the mindfulness and growth mindset approach (MAGMA) in decreasing math anxiety in students in various STEM-related courses, and with different instructors. Results indicate that overall, students' self-perceived math anxiety decreased significantly compared to their control counterparts. Furthermore, considerable anxiety reduction was found for female students. However, no differences were found for final exam scores between the intervention and control group. Nevertheless, the MAGMA intervention appears to be an effective, inexpensive approach in alleviating math anxiety, and increasing mathematical resilience in community college students as they take STEM-related courses.

"I Can Math, Too!": Reducing Math Anxiety in STEM-Related Courses using a Combined Mindfulness and Growth Mindset Approach (MAGMA) in the Classroom

Quantitative reasoning and advanced mathematical aptitude are essential skills for many STEM-related occupations that many students desire to pursue. In order for students to be successful in required math college courses, appreciate the value of math for their desired career, and appropriately apply mathematical knowledge, engagement in math content is necessary. However, approximately 80% of community college students have reported experiencing symptoms of math anxiety (Yeager, 2012). This negative cognitive-affective reaction is characterized as an overwhelming feeling of "panic, helplessness, paralysis, and mental disorganization" concerning the ability to solve mathematical problems (Tobias & Weissbrod, 1980). Math anxiety inhibits learning, creates self-doubt about math competence, leads to poor test performance, and reinforces the initial belief of low self-efficacy. This aversive response to math situations typically results in "global avoidance" in students (Ashcraft & Faust, 1994), which include: low attendance, lack of math engagement, lack of effort in attempting or completing math problems, and withdrawing from math-related courses and disciplines. Academic consequences (failing exams, failing courses, probation status) could be quite discouraging for these high math-anxious students, which could also diminish their sense of academic belonging.

According to the literature, math anxiety is a primary reason women and ethnic minority students avoid pursuing advanced mathematics and science courses (Ercikan et al., 2005). In light of overwhelming research regarding the damaging effects math anxiety has on students' self-perceived math competence (Bekdemir, 2010), mathematical persistence and resilience (Johnston-Wilder et al., 2014), academic performance (Betz, 1978), and educational disparity

(Beilock & Maloney, 2015), we argue that math anxiety is an academic social justice concern. This phobia for math deters many promising community college students from passing developmental math courses, pursuing STEM majors, or persisting in STEM-related disciplines they do declare. Consequently, math anxiety promotes mediocrity, further widens the educational gap, and poses restrictions on future career opportunities, especially for those from marginalized populations (e.g., underrepresented ethnic groups, female students, students with intellectual disabilities). It is quite evident that there is a national imperative and commitment to tackle student attrition, and underrepresentation in STEM-related disciplines and occupations. However, math anxiety is a largely unexplored but essential variable, and intentionally addressing this pressing issue would substantially promote equity for these vulnerable students. Although an abundance of research has investigated underlying cognitive processes that contribute to math anxiety, there is limited research leveraging this knowledge to develop embedded instructional strategies in an effort to explicitly address this problem. The current research builds on a successfully pilot-tested mindfulness and growth mindset intervention (Samuel & Warner, 2021) designed to alleviate math anxiety in community college students.

Understanding the cognitive process underpinning math anxiety is essential before determining interventions to counteract its effects. Contrary to popular belief, math anxiety does not merely occur when students are working on math problems. According to research by Lyons and Beilock (2012), distress is first triggered when students are anticipating a math situation, or a cue that a math task is imminent. Situational anticipatory factors (e.g., walking into the math classroom, waiting for instructor to begin lesson or distribute exams) that induce pessimistic thoughts in a math-related context significantly contributes to execution anxiety. The incapacitating nature of this psychological phenomenon during the anticipatory phase is also

related to the way in which the mind temporarily processes newly attended information. Working memory is our "mental scratchpad," and has limited capacity, with a duration of about 15–30 seconds (Baddeley, 1992; Atkinson & Shiffrin, 1971). In high math-anxious students, excessive rumination about failure consumes this system, significantly depletes the mental bandwith necessary for executing mathematical problems at hand, and results in poor performance. Furthermore, research by Mattarella-Micke et al. (2011) suggests that performance in high math-anxious students with high working memory capacity is compromised based on students' interpretation of their physiological arousal when presented with difficult math problems to solve. Their interpretation of the math situation as panic-inducing, causes them to "choke" or "blank out," resulting in higher error rates. Focus on reducing anticipation anxiety is essential, as most interventions have been designed to target only execution anxiety, which appears to be more salient in expression. Considering the disruptive and taxing effects that math anxiety has on working memory, mindfulness, an intervention that promotes a calm state of mind, has worked well to alleviate anticipatory stress. Mindfulness is the non-judgmental, intentional awareness of the present moment (Kabat-Zinn, 2015), and involves deep breathing and meditation exercises to facilitate a tranquil mental state in an effort to disrupt negative rumination. Because it requires a deliberate focus on being fully present, this evidence-based practice is known to counteract anxiety symptoms, as it also operates on the working memory system (Course-Choi et al., 2017). As a result, working memory reserves are not exhausted by negative thoughts, but instead are available to execute the current academic task. With regards to math-specific anxiety, mindfulness has been found to reduce math anxiety in 4-year college undergraduate students (Bellinger et al., 2015).

Mathematical understanding is often considered as an inherent talent; “a subject as a sort of elitist wizardry” (Bond & Chernoff, 2015). Students often complain that math does not seem accessible to them (Sole, 2019) – and this “either you have it, or you don’t” mentality becomes self-sabotaging if students truly believe they fall in the latter category. According to Dweck (2008) this fixed mindset is a dispositional theory of intelligence; and as it relates to math, is the belief that proficient mathematical understanding is intrinsically acquired. In the math classroom, fixation on performance goals (i.e., high exam scores/course grades) causes at-risk students to reconsider their competence. In fact, according to Choe et al. (2019), math-anxious students often negotiate the cost for engaging in math and typically avoid high stakes math problems, even when these problems are highly incentivized. This fixed mindset is problematic, as it reinforces complacency – causing failing students to lack motivation to persist when they struggle. When faced with challenging, multiple-step problems, students simply stop trying, as they believe that their effort to continue is futile. Even proficient students could be affected by this phenomenon, as their early achieving grades could lead some of them to coast, fail to check for errors, and become less accepting of critical feedback. Nevertheless, regardless where students fall on the academic spectrum (proficient, or in danger of failing), students endorsing a fixed mindset while taking a math course tend to avoid challenges to master new skills; resulting in poor performance, risk of failure, and a discouraged attitude toward math. This fixedness on failure is a self-perpetuating cycle that could potentially continue across semesters – whether students fail and end up retaking the course, or have barely passed, and proceed to take a more advanced math-related course.

Alternatively, the concept of growth mindset shifts many underlying assumptions that have been socially ingrained in students about intelligence, mathematics and math education.

Grounded in the concept of neuroplasticity, growth mindset is the belief that intelligence is malleable; and that with practice, abilities and performance for a challenging skill can improve over time (Dweck, 2008; Yeager & Dweck, 2012). Within the classroom setting, instructors are extremely vital in instilling and reinforcing this concept in their students by educating students about adopting a growth mindset early on, setting high expectations for their students, and specifically describing explicit ways in which they could provide support to their students. Additionally, instructors' sustained efforts in reminding students about the positive effects of growth mindset principles is also essential in fortifying students' confidence in their ability to learn mathematical material.

Given what we know about math anxiety, how should instructors teaching math-related courses engage and motivate their students each class session, over the course of the semester? Directly embedding psychological interventions within classroom pedagogy has been recommended to make stress management methods immediately accessible to many students (Spitzer & Aronson, 2015). Many research studies have either implemented a mindfulness (Cavanagh et al., 2021) *or* a growth mindset intervention (Fleurizard & Young, 2018; Smith & Capuzzi, 2019) to allay math anxiety in the college classroom. In an attempt to sustain a calm state of mind, and confidence in math ability throughout an entire class session, we propose that a combined mindfulness and growth mindset approach is necessary to alleviate both anticipation and execution anxiety. The *mindfulness and growth mindset approach* (MAGMA, or MAGMA intervention herein) combines both concepts, in order to disrupt negative rumination and affect toward math, build confidence in working on math-related tasks, and promote attention and engagement during the entire class session. There is little to no research that has developed interventions to specifically counteract anticipation and execution anxiety in community college

students. The pilot research was the first attempt at systematically mitigating these phases of anxiety that occur in students in a classroom setting. The results revealed that implementing a combined mindfulness and growth mindset approach effectively decreased math anxiety and increased math self-efficacy for students. The previous study involved only one course (Statistics) taught by one instructor. The current research investigated the effectiveness of the intervention on a larger scale. To assess replicability of the MAGMA intervention, several different STEM-related classes taught by different instructors were recruited.

The current research examines the following questions: (a) What effect does implementing the MAGMA intervention have on reducing math anxiety, and increasing math self-efficacy in community college students taking STEM-related courses with different instructors? (b) How was the MAGMA intervention received by students and instructors? (c) To what extent does the MAGMA intervention replicate and extend findings from the pilot research? Our primary hypothesis was that math anxiety would significantly decrease from pretest to posttest in students receiving the MAGMA intervention over the course of the semester compared to the control group. Although math-self efficacy scores from the pilot research only yielded significant differences for individual school subjects (e.g., statistics), and not overall scores, we hypothesized observing an increase in overall scores for the current research due to the larger sample size. Furthermore, an ad hoc investigation of whether student exam scores would increase as a result of the MAGMA intervention was scheduled to be conducted only if the primary findings revealed that the intervention was indeed effective in reducing math anxiety. Since the current research is a replication of the pilot study, much of the intervention procedure remained the same, except for a few minor modifications to improve the quality of the methodology.

Method

Setting. The current research took place at Guttman Community College, a small northeastern urban public institution in the United States. A designated Hispanic Serving Institution (HSI), the student body at Guttman Community College is comprised of a high proportion (>95%) of underrepresented racial and ethnic groups. IRB approval (#2017-0760) was obtained from the college's ethics board to administer the intervention in the classroom, and to access exam scores from consenting students and instructors.

Participants

Faculty. During the end of the Spring 2019 semester, recruitment e-mails were sent to full- and part-time faculty. Only faculty members who responded to the e-mail, and were scheduled to teach a STEM-related course in the Fall 2019 semester were considered for recruitment. A total of 7 faculty members (n = 6 full-time; n = 1 part-time) from the following STEM courses participated in the experiment: Statistics, Quantitative Reasoning, Information Technology, Macroeconomics, and Introduction to Business.

Students. At the beginning of the Fall 2019 semester, a total of 157 students (81 females, and 76 males; mean age: 18 years, 7 months) were recruited to participate in the research from the following STEM courses: Statistics, Quantitative Reasoning, Introduction to Business, Macroeconomics, and Information Technology. A total of 13 course sections were randomly assigned to either the treatment (MAGMA) condition, or control condition (standard instruction as usual).

Procedure

Faculty summer professional development workshop: MAGMA training

An 8-hour workshop in the summer was developed to prepare faculty with information on how to implement the MAGMA intervention in their classes for the upcoming Fall 2019 semester. The purpose of this workshop was to provide instructors with: a) an experiential and theoretical understanding about *mindfulness* and *growth mindset* principles; b) information about the rationale for the research, intervention procedure, and results of the pilot study; and c) logistics for implementation in the testing semester. In order for participating faculty to fully comprehend mindfulness and growth mindset theories, it was crucial that the training session was deeply experiential. Participants were guided through a series of individual and group contemplative activities in an effort to develop personal significance of mindfulness and growth mindset principles, and to consider their math-related course from their students' perspective. Furthermore, based on the qualitative data from the previous research, it was emphasized to faculty that they lean into the intervention by leading the mindfulness and growth mindset affirmations with authority and conviction.

Testing semester

On the first day of classes in Fall 2019, a member of the research team announced the purpose of the research to each treatment and control class. An oral recruitment script was used to provide informed consent, which was approved by the IRB. Students were informed of their right to opt out of the study by declining to complete the survey. All consenting students were asked to fill out two online anonymous surveys: a) a math anxiety questionnaire, and b) a math self-efficacy survey. All 7 instructors indicated that all of their students consented to participate in the research at the beginning of the semester.

Intervention: Mindfulness and Growth Mindset Approach (MAGMA)

Beginning on the second day of classes, all treatment sections participated in the MAGMA intervention. Instructors showed videos that illustrated the concepts related to mindfulness and growth mindset principles (presented only on the first day of the intervention). In an effort to address *anticipation anxiety*, at the start of each class session (beginning of the second day of classes until the end of the semester), each participating professor rang a chime once, and announced to their students that the deep breathing exercise will commence. Students were reminded that participation was voluntary, but if they did not want to participate, to refrain from distracting others during the deep breathing session. They were also told that participation, or the lack thereof, had no bearing on assessments in the course. Instructors asked their students to close their eyes, to focus on the present moment, avoid retrospective thinking, or what they would anticipate would happen in class after the breathing exercise. Instructors then led students through a guided breathing exercise of 10 deep breaths. Instructors then prompted students to state five growth mindset statements aloud, with enthusiasm (i.e., "I am capable of understanding math," "Today's lesson might be challenging, but I'm up for the challenge"). All growth mindset affirmations were the same ones developed by Samuel & Warner (2021). See Appendix for the complete set of growth mindset affirmations. Statements were presented on a PowerPoint slide, while both the instructor and students recited the statements in unison. Instructors then continued with teaching the lesson planned for that day. To reduce *execution anxiety*, the professor a) reminded students to focus on the present moment during the lesson, and when feeling anxious, to take deep breaths as needed; b) emphasized the importance of effort, persistence, and openness to constructive criticism; and c) provided verbal praise in response to behaviors related to effort, and endurance. Instructors reframed any fixed mindset statements with euphemisms that promote growth mindset. Finally, instructors were asked to refrain from using red pens in

grading their students' work to minimize this extraneous variable that implicitly induces anxiety in students as they typically associate red ink with failure (Moller et al., 2010). Research by Rutchick et al. (2010) has also found that instructors also unconsciously evaluate their students' work with a negative bias when the color red was used for correction.

Mid-semester reinforcement

To reinforce student persistence over the course of the semester, 2– 5 × 7 informational resource cards about mindfulness and growth mindset principles were distributed to all students in the treatment classes. The cards were developed to serve as a tangible reminder for students beyond the classroom setting. It should be noted that this mid-semester reinforcement was an enhancement to, but not included part of, the original intervention in the pilot study.

Control group

Students in the control class sections did not receive the MAGMA intervention. Students in these sections received standard instruction over the course of the semester.

Dependent measures

Quantitative data collection

Two surveys were administered online to all consenting students in the Intervention and Control groups: a math anxiety survey (AMAS), and a math self-efficacy survey (MSES). Students from both conditions completed these anonymous surveys at two periods during the Fall 2019 to assess these dependent measures: a) on the first day of classes, and b) during the last week of the semester. Demographic information was asked after surveys were completed to minimize stereotype threat in students (Steele & Aronson, 1995).

Math anxiety assessment

The previous research (Samuel & Warner, 2021) assessed math anxiety using the Math Anxiety Rating Scale-Revised (MARS-R; Plake & Parker, 1982). For the current research, we opted to administer the brief Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003). The AMAS is a 9-item instrument that was developed to address limitations related to the MARS-R. Items on the AMAS are rated on a fully anchored 5-point Likert scale ranging from 1 (low anxiety) to 5 (high anxiety).

Math self-efficacy assessment

Students' math self-efficacy was assessed using the 34-item revised Math Self-Efficacy Scale (MSES; Betz & Hackett, 1983). This survey measures self-perceived competence in solving mathematical problems in the classroom setting, tasks that involve numerical literacy in everyday life, and their confidence in succeeding in math-related courses. The MSES uses a 10-point Likert scale ranging from 0 (no confidence at all) to 9 (complete confidence).

Qualitative data collection (focus groups)

Student focus group

During the last week of classes, a randomly selected group of students from treatment groups from each type of course re-consented to participate in a focus group interview. In this semi-structured interview, students were asked to discuss their prior knowledge and experience with mindfulness or growth mindset concepts, and to reflect on their self-perceived math anxiety and math self-efficacy over the course of the semester.

Instructor focus group

At the end of the semester, consenting faculty participated in a focus group. This semi-structured interview used guided questions to ask instructors to reflect on perceived math anxiety

in their students over the course of the semester. They were also asked to reflect on the administration, and self-perceived effectiveness of the MAGMA intervention in their students.

Results

Attrition. From the initial sample of 157 students, there were 2 classes that were excluded from the final analyses (N = 29). One instructor withdrew their class assigned to the treatment condition (*n* = 13) from the research due to what was described as lack of student participation with the intervention during the second week of the semester. Although both AMAS and MSES pretest scores were obtained from all students, data were not recorded for posttest scores for this class. The instructor also declined to administer post-surveys to their designated control class at the end of the semester (*n* = 16). Since posttest data is necessary in order to ascertain differences compared to baseline (pretest data), these cases were excluded from the group analysis.

Math anxiety analysis (AMAS)

Response rate and data reduction. From the remaining 128 students in the sample, there were a total of 26 incomplete surveys. Only data from students who had completed both pre- and post-surveys were included in the final quantitative analyses. The resulting student sample was N = 102 (*n* = 60 females, *n* = 42 males), yielding a 65% response rate.

Normality testing. Data were entered and organized in Excel, then analyzed using SPSS version 25. An analysis was conducted on the difference scores to test the normality assumption of AMAS pretest and posttest data. The Shapiro-Wilk test revealed that the difference scores were approximately normally distributed for both Intervention and Control groups (p's > .05). A visual inspection of histograms, Q-Q plots, and boxplots substantiated these results. Therefore, we continued data analysis using parametric tests.

Preliminary analysis

For this pretest posttest quasi-experimental design, a preliminary independent *t*-test (with Levene's test $p > .05$) confirmed the assumption of no significant differences of pretest scores between groups: Intervention (M = 30.14, SD = 7.02), Control (M = 30.13, SD = 6.96), t (101) = .011, $p = .992$.

Within-groups analysis

A paired sample *t*-test was then conducted to test the hypothesis that math anxiety would reduce over the course of the semester in the treatment group as a function of the MAGMA intervention. A one-tailed *p*-value is reported due to the strong prediction of this direction based on the pilot data. Results indicate that math anxiety scores were lower at the end of the semester (posttest: M = 25.89, SD = 7.67), compared to the beginning of the semester (pretest: M = 30.14, SD = 7.02), t (70) = 4.261, $p < .001$, $r = .45$, a medium-large effect size. No differences were found for the Control group over the course of the semester (pretest: M = 30.13, SD = 6.96; posttest: M = 29.66, M = 7.64), t (31) = .402, $p = .345$, *n.s.* Figure 1 illustrates the treatment group's considerable decline of math anxiety scores compared to their control counterparts over the course of the semester.

Gender differences

We conducted an analysis to determine if there were any gender differences in the treatment group. Preliminary tests to check normality assumption indicated no violations, as the Shapiro-Wilk statistic confirmed that difference scores were normally distributed for female and male subgroups (p's > .05). Histograms, normal Q-Q plots, and box plots for each distribution were approximately normal. An independent *t*-test was conducted to assess baseline scores between females and males, which revealed that at the beginning of the semester, females had a higher math anxiety rate (M = 31.81, SD = 6.33) than their male counterparts (M = 27.87; SD =

7.37). This is not surprising, since females tend to experience high math anxiety levels in math situations, usually due to preconceived notions about gender and math ability (Maloney et al., 2013). However, paired samples t-test analyses revealed that for the treatment condition, over the course of the semester, females' math anxiety scores decreased significantly at posttest (M = 26.85, SD = 7.74) compared to their pretest scores (M = 31.81, SD = 6.33), t (40) = 4.265, p < .001, r = .56, a large effect size. However, for males, no differences were found between pretest scores (M = 27.87, SD = 7.37) and posttest scores (M = 24.57, SD = 7.50), t (29) = 1.875, p = .071, *n.s.* Figure 2 illustrates the gender differences of math anxiety scores.

Math self-efficacy analysis (MSES)

Response rate and data reduction. Out of 128 students, there were 40 cases of incomplete surveys, which were excluded from the final analysis. The resulting sample was N = 88 students (n = 53 females, n = 35 males) who completed both pre- and post-MSES surveys, yielding a 69% response rate.

Preliminary analysis

For the math self-efficacy assessment, a preliminary analysis was conducted to test the normality assumption on the pre- and post- difference MSES scores between the treatment group (n = 57) and the control group (n = 31). The Shapiro-Wilk test indicated that the difference scores for the control group violated the normality assumption (p = .027). Further examination of the data indicated that the distribution was skewed (.994; SE = .421), but within range for kurtosis. However, the treatment group difference score distribution was found to be normally distributed (p = .821). The shape of the distribution for both groups were confirmed by visual inspections of the histograms, Q-Q plots and boxplots. Due to the non-normal distribution for the control group, we proceeded to analyze the data using nonparametric tests. A Mann-Whitney independent

groups analysis was then conducted on pretest scores for both groups to confirm the assumption that these scores were not significantly different from each other. Pretest scores for the Treatment group (*Mdn* = 3.71) did not differ significantly from the pretest scores for the Control group (*Mdn* = 4.32), U = 737, $z = -1.280$, $p = .201$ *n.s.*

Within-groups analyses

To assess whether there was a difference between the pretest and posttest scores, we analyzed the data using the nonparametric Wilcoxon signed-ranked test. The test indicated that for the treatment group, math self-efficacy substantially increased at posttest (*Mdn* = 4.38) compared to pretest (*Mdn* = 3.71), T = −2.443, $p = .015$, $r = -.23$, a small/medium effect size. However, the data revealed that for the control group, math self-efficacy had also increased at posttest (*Mdn* = 5.06) to pretest (*Mdn* = 4.32), T = −2.676, $p = .007$, $r = -.34$, a medium effect size. Since math self-efficacy had also increased for the control group, we did not pursue further analyses on the treatment group.

Exam scores

Since the data indicated that the MAGMA intervention was effective in reducing math anxiety, we were interested in whether student grades had also increased as a result. A total of 3 classes (Statistics: treatment n = 25, control n = 31; Quantitative Reasoning: treatment n = 33, control n = 15; Introduction to Business: treatment n = 22, control n = 14) were recruited from instructors who consented to provide this information. For each course, an analysis was conducted to determine if students' exam scores from the last exam administered was considerably higher for students in the treatment condition compared to the control group for the same course. Since the post-scores revealed low math anxiety rates for the treatment group, the intervention may also influence students' grades for their last exam. Preliminary analyses confirmed approximate

normality for the distribution of scores for treatment and control groups for each course (Shapiro Wilk *p*'s > .05). Independent t-tests were conducted for each course (Levene's test p's > .05), which indicated that for the last exam, no significant differences were found between treatment and control groups: for Statistics, t (54) = −.333, p = .740; for QR, t (46) = −1.170, p = .248; for Intro Business, t (34) = .473, p = .639. Based on the results, we refrain from concluding that the MAGMA intervention had any effect on student grades.

Qualitative data collection (focus group): Post-intervention reflection

Students. Seven randomly selected students from treatment classes consented to participate in a semi-structured focus group interview during the last week of classes. The focus group interview, which lasted for approximately 49 minutes, asked participants about their impressions of the intervention.

Thematic content analysis was used to analyze the qualitative data (Cresswell et al., 2011), which yielded three themes related to elements of the MAGMA intervention, and the effectiveness of the MAGMA intervention. The themes are the following: 1) *deep breathing reduces math anxiety and helps to persist*, 2) *mindfulness is helpful outside of class*, and 3) *saying growth mindset affirmations gives math confidence*.

Deep breathing reduces math anxiety and helps to persist: When students were asked about their perception of the mindfulness activity, many remarked that they found the exercise valuable, as it not only helped to alleviate their math anxiety, but it also helped them persist. One student remarked, "When I'm stressed before an exam, just breathing helps me get through it."

Mindfulness is helpful outside of class: When asked about whether they had used the intervention to relieve stress outside of the classroom setting, several students found value using elements of the intervention in other contexts. One student stated, "I do [the mindfulness

exercise] rather frequently because I have personal issues, so it helps me with that so that I stop panicking … like in everyday life"

Saying growth mindset affirmations gave them confidence: When students were asked about their perceptions of saying the growth mindset affirmations, many remarked that saying them aloud gave them confidence in math: "I like saying the positive statements … at first this whole thing was weird because I didn't believe them, but saying them out loud everyday motivated me and built my confidence for the rest of the class."

Instructors. An exit interview was also conducted for participating instructors at the end of the semester. A total of 2 instructors consented to participate, and the interview lasted for approximately 46 minutes. The data reported are themes and noteworthy statements from the instructors about their impressions of the intervention:

The importance of routine for implementing the MAGMA intervention: "I think it's important to do it regularly. One day I forgot my flashdrive which contained the file to prompt students for the breathing and affirmations. I immediately thought that the class was going to be affected for that day. That was my feeling and so I just led the class through the entire intervention from memory. I think it's important for effectiveness. Prepare them for class, and to create that discipline."

The importance of mindfulness for both students' and instructors' benefit: "I found myself doing breathing in the stairwell on the way down before class … I always thought about student names when doing the deep breathing to settle myself and prepare myself because of the challenges for the class."

Importance of growth mindset affirmations and student enthusiasm: "Honestly, sometimes it threw me a bit to see the enthusiasm with which many [students] would just say

them and I would read them all with them. It's somewhat encouraging and surprising … students would actually say them out loud, like a mantra, very loudly repeat them and I didn't expect that, just them getting into it."

The qualitative analysis indicated that students found the MAGMA intervention to be quite effective in reducing math anxiety in the classroom, and had also utilized it in other stress-induced contexts. Declaring growth mindset statements, with professors reinforcing this concept throughout class instruction, was instrumental in increasing students' mathematical competence.

Discussion

The current research is a replication of previous pilot research by Samuel & Warner (2021) in an effort to substantiate the effectiveness of a combined mindfulness and growth mindset-based intervention (MAGMA) for the purpose of alleviating math anxiety in community college students. In particular, we tested the generalizability of the MAGMA intervention in various STEM-related courses, taught by different instructors over the course of a semester. The results indicate that on a larger scale, the findings were indeed replicable in reducing math anxiety compared to classes that had only received standard instruction. One unanticipated finding is that although females reported higher levels of math anxiety at the beginning of the semester, the intervention had a positive impact, as their levels of anxiety substantially diminished over the course of the semester. In addition, although math self-efficacy scores had also surged in students from the treatment group, the control group also demonstrated a similar increase. One possible explanation for these gains in the control group could be residual effects of instructors leaning into the intervention caused them to inadvertently create a culture of growth mindset to students in their control classes. The qualitative data had substantiated the quantitative data: overall, students found value in practicing mindfulness and growth mindset

intervention, both within and beyond the classroom. Participating instructors have also expressed that the intervention not only instilled a positive culture in the classroom, but also found it to be a useful pedagogical tool.

Although the intervention was successful in alleviating math anxiety and increasing math self-efficacy in students, one limitation is that there were seemingly no differences in students' last exam scores compared to the control group. Besides the low sample size of courses analyzed, another explanation could be related to the kinds of assessments administered to students in some of these courses. For instance, for the Introduction to Business course, a significant part of the grades (i.e., business case analyses, presentations, reflections) do not measure math skills, per se. Nevertheless, the intervention had instilled skills to help students regulate their anxiety under pressure, and persist while working on difficult math problems over the course of the semester. These are valuable transferable skills that could be used in a wide variety of contexts, including occupational pursuits. Another limitation of the research is that implementing the MAGMA intervention requires a great deal of instructor buy-in, otherwise the results will fail to replicate. The comprehensive review by Yeager, Carroll, Buontempo, et al. (in press) supports this notion – that instructors should provide a supportive context when implementing growth mindset interventions, which helps students to embrace these attitudes and engage in course content. In fact, a theme that had emerged in the pilot study was that students appreciated that the instructor authorized and participated in the intervention by leading the breathing exercise, and stating the positive affirmations with conviction. Initial lack of student participation is to be expected, as math anxiety and fixed mindsets foster rigid, self-defeating attitudes. However, instructor persistence in reinforcing the concepts, in conjunction with the repetitious procedure built into the intervention helps to promote student buy-in over time.

Passive instructor participation, or lack of conviction and commitment to the process are counterproductive, and students may perceive this unconvincing attempt to motivate them as a tremendous waste of effort.

That the majority of community college students in the United States report experiencing high levels of math anxiety (Yeager, 2012) is frankly, a statistic that is irresponsible to disregard. For many students, math anxiety and lack of confidence in mathematical ability have long been such a consistent struggle for much of their academic life that it is no wonder "choking" occurs when presented with a math situation. Yet little has been done in terms of developing initiatives that specifically address math anxiety in students. If we are to think about ways to improve retention rates, and promote minority representation in STEM occupations, addressing math anxiety is one course of action to fix this leaky pipeline and promote academic momentum. Additionally, the association between failure in math classes and inherent ineptitude for math is a fallacy. Instructors and institutions at large espousing fixed mindset attitudes perpetuate a Golem effect, whereby lowered expectations of these students lead to poor academic achievement, induce further apprehension as they take required math courses, and discourage them from pursuing STEM majors. Disinterest in STEM disciplines to avoid the required math courses results in fewer candidates in the labor force eligible for STEM occupations (Camp, 1997), which could have economic implications. Thus, it is imperative that a social justice perspective on teacher education specifically addressing math anxiety and math competence in students is warranted to increase math readiness, especially focusing on those at-risk subgroups who are "socially, financially, and academically underprepared and unsupported" (Vivian, 2005).

The purpose of the MAGMA intervention is to prioritize students' well-being when encountering math situations in the academic setting. Given that math situations tend to invoke

anxiety and negative attitudes, MAGMA is a non-judgmental intervention that intentionally reserves time in class for students to center themselves, while building confidence in their ability to do math problems. The regimented nature of the MAGMA intervention is essential in overriding stubborn fixed mindsets about math that had been reinforced for many years. Instructors serve as a steel rod of support to buffer against doubts that may arise in students as they learn new math concepts, and productively struggle while applying their knowledge. This aligns with research by Yeager et al. (in press), indicating that the powerful influence instructors have in cultivating a supportive growth mindset environment greatly increases the likelihood that students will firmly believe in the efficacy in adopting these mindsets. Intentional infusion of growth mindset in the context of the classroom, in fact, had a greater effect for students than when they attempted to apply this principle independently. In the previous research, students have stated that the routinized practice made them believe the growth mindset affirmations to be true. In the current research, students had echoed the same sentiment, and instructors also mentioned how the routine created a sense of discipline and set the tone for the class. The results of the research revealed that female students, a subgroup susceptible to stereotype threat, had benefited from the intervention – despite higher levels of anxiety at the beginning of the semester, had significantly reduced math anxiety by end of the semester. Given that the population of students at Guttman Community College are primarily from ethnic minority and other underrepresented groups, this intervention appears to be a seemingly promising approach that communicates to students that math anxiety can be reduced, that math is indeed accessible, and that they are capable of learning it. Instructors teaching math-related courses could find utility in the intervention as part of their arsenal of pedagogical tools to help boost confidence and bridge the achievement gap in their students. The data for the current research was collected

shortly before the COVID-19 pandemic. Considering how the pandemic has, and continues to wreak havoc on many students, professors have limited insight with regards to what many of their students may be experiencing in their personal lives. With a deep breathing exercise to begin each class session, followed by stating positive affirmations, with an understanding that mistakes are not failures – a certain level of grace had been built in the intervention that hopefully, some students (and instructors) may appreciate.

The findings of the pilot research and the current replication have demonstrated that the MAGMA intervention appears to be an effective, accessible, yet cost-prohibitive approach that empowers students and promotes academic resilience. Future research will examine the effects of this equity-oriented approach to investigate academic anxiety reduction for non-math disciplines. Although mathematics commonly induces intense negative emotions contributing to self-perceived anxiety and doubt within students, academic anxiety is not limited to mathematics. Since MAGMA is not math-specific, it could be customized to address anxiety and fixed mindset attitudes for other kinds of courses, and anxiety-provoking tasks. The next phase of the research program will be to investigate generalizability of this research beyond the STEM disciplines; particularly examining reading and writing anxiety for English Composition, and other writing-intensive courses. Additionally, since mindfulness has been found to reduce social anxiety (Goldin & Gross, 2010), future research could also examine the extent to which MAGMA is effective in regulating social anxiety to help students with presentations and interviews in other contexts. Essentially, significant findings from the current research project would serve as foundational evidence and justification to further test its applicability for any cognitively demanding subject area or skill that has been stigmatized by students as being extraordinarily difficult.

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Appendix.

Daily Growth Mindset Affirmations

On non-exam days:

1. Professor (LAST NAME) believes I can understand today's lesson.

2. I am capable of understanding math.

3. Today's lesson might be challenging, but I'm up for the challenge.

4. I expect to make mistakes today, and then learn from those mistakes.

5. Math is beautiful/magical when I see how it all fits together.

On exam days:

1. I know I am capable of doing well on this exam!

2. I've got this!

Figure 1

Mean pre- and post- math anxiety scores over the course of the semester for the MAGMA Intervention group and the Control group (no intervention)

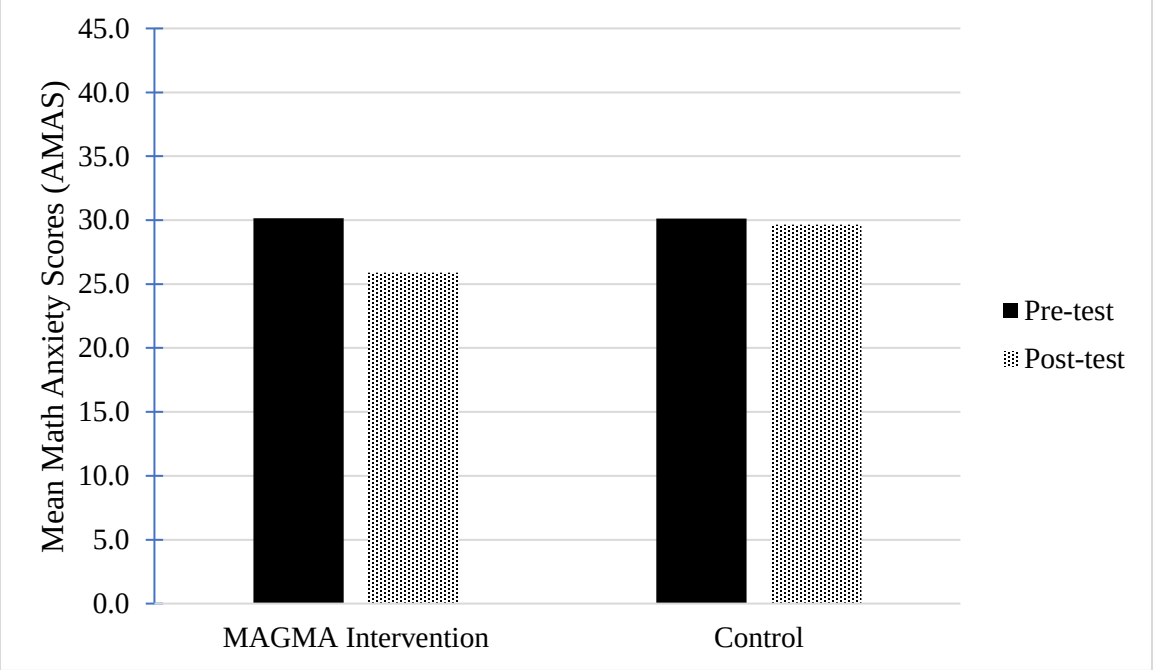

Figure 2

Mean pre- and post- math anxiety scores over the course of the semester for female and male students receiving the MAGMA intervention