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Unmotivated, Depressed, Anxious: Impact of the COVID-19 Emergency Transition to Remote Learning on Undergraduates' Math Anxiety

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Synopsis

In summer 2020, we invited the 6761 undergraduate students who took a Spring 2020 math course at the University of Arizona to participate in a survey, with 13% responding. We asked about their experience with the emergency transition to remote learning and measured their math anxiety before and after the transition using the well-established Abbreviated Math Anxiety Scale (AMAS). "Unmotivated, depressed, anxious" are the words one undergraduate used to describe their emergency transition to remote learning. Our results indicate that limited access to quality technology and inadequate communication with an instructor were the two greatest predictors for an increase in math anxiety after the emergency transition to remote learning. These results may encourage instructors to foster community with their students, especially during emergency remote learning.

Keywords: *math anxiety, emergency remote teaching, COVID-19, equity.*

1. Introduction

Math anxiety is commonly characterized by negative feelings that disrupt someone's ability to manipulate numbers or solve math problems, either in an academic setting or in day-to-day life [23]. This anxiety can be mild (e.g. mild apprehension before an exam) or severe (e.g. overwhelming emotions and a phobia of mathematics) [3]. Math anxiety has been shown to cause a decline in academic performance, independent of an individual's mathematical competence [2] and is inversely correlated to math achievement, with high math anxiety negatively impacting school grades and standardized test scores [9].

Math anxiety is of particular concern among undergraduate students. Math anxiety causes an individual to have little confidence in their ability to undertake mathematical problems [27]. Students with high math anxiety tend to take fewer mathematics courses and show less intention to take more college mathematics courses, thus limiting their career options [11]. As a result, an individual student's math anxiety impacts student enrollment in higher education, thereby limiting employment opportunity for the individual, with serious social justice implications [5, 28]. Thus, in this novel age of widespread remote learning, it is vital to conduct research into issues of math anxiety and avoidance in science, technology, engineering, and mathematics (STEM) related degrees.

As with various forms of anxiety, recognizing the symptoms and developing coping strategies can be helpful in controlling anxiety. While there is no one-size-fits-all cure for math anxiety, many anxiety reduction approaches require the mathematically anxious student to take some initiative in their learning process [25]. Furthermore, educators have been shown to play an important role in not only recognizing and raising awareness of math anxiety, but also guarding against negative classroom environments and helping students to build confidence [11, 24, 26]. Some researchers have also focused on what classroom factors increase mathematics anxiety among students. For example, an instructor with an argumentative or aggressive communication style can increase their students' math anxiety levels [18]. Additionally, a teacher with high levels of math anxiety or negative attitudes towards math can pass that anxiety or negative attitude on to their students, resulting in poor learning outcomes [17].

Our study focuses on recognizing and improving factors that contribute to anxiety in both in-person and online formats. In particular, what aspects of the Spring 2020 COVID-19 emergency transition to remote learning increased undergraduate student's math anxiety? The immediate and involuntary nature of the transition posed unique challenges. Accordingly, while we consider many well-established stressors, such as poor instructor-student communication, we also consider atypical potential stressors that would not appear in a traditional in-person classroom, such as reliable access to the internet.

Organization.

In Section 2, we outline the events of the University of Arizona's transition to remote learning as a result of COVID-19. An overview of the methodology in Section 3 includes an introduction to the survey items utilized in measuring math anxiety as well as a brief validation of our overall survey results. Following the survey's implementation, we conducted statistical analysis to uncover trends in students' change in math anxiety as related to self-reported information, including demographics, technology access, and experiences during the semester. The results of this analysis are discussed in Section 4. Finally, Section 5 includes a discussion of key results with some advice for educators. Concluding remarks appear in Section 6.

Acknowledgements.

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2. Transition to Remote Learning

We will use the following terminology to distinguish between the time periods before and after the University of Arizona's transition to remote learning:

- before the transition: Spring 2020 semester before spring break, i.e. January 15 through March 6.
- after the transition: Spring 2020 semester after spring break, i.e. March 18 through May 15 2020. During this period, all university courses were online only.

Departmental course structure

Mathematics courses at the University of Arizona (UA) are taught by research faculty, instructional faculty, post-doctoral researchers, and graduate students. Small class size is emphasized, with the large majority of classes having an enrollment capacity of 35 students or less. However, a few classes have a larger capacity of 60 students, and approximately 3 classes hold large lecture sections with 200-300 students.

During any given semester, the majority of enrolled students take some version of college algebra, precalculus, or calculus. There are multiple versions and sequences of college algebra and calculus. Classes up through calculus are typically taught by instructional faculty and graduate students, with the help of undergraduate teaching assistants. Research faculty and post-doctoral researchers typically teach courses at the calculus level or higher.

Many of the entry level courses, like college algebra and calculus, are coordinated courses that use a common calendar, online homework portion, and final exam. Written homework and/or quizzes vary according to specific sections within each course. When being taught in person, many of these classes typically utilize collaborative learning spaces that include student whiteboards, grouped desks, multiple large whiteboards and projectors to encourage group work. Before the transition, course offerings were either completely online or completely face-to-face (no hybrid courses prior to the transition).

Class information (announcements, grades, etc.) is generally available via the university's learning management system, D2L (Desire to Learn). Each instructor/professor is required to schedule 3-4 office hours per week depending on the course.

Class expectations prior to the transition

The Department of Mathematics offered over 400 class sections during Spring 2020, with fewer than 15 of these sections offered as an online course. For nearly all courses, assessments were given on paper, individually or in groups, to be physically handed in to the instructor. Students who had accommodations for test-taking typically arranged their exams with campus Disability Resource Center. During assessments, technology resources were limited to a handheld scientific or graphing calculator (not including cell phone calculator applications). The libraries provided calculators and other technology items for students to check-out for two weeks at a time. The implementation of other communication outlets (GroupMe, Discord, Piazza, and other social media) was present although not typical. Lectures were rarely recorded, although many coordinated classes offered standardized example videos for specific problems. Each faculty member held one office hour in a departmental or campus tutoring center.

Making the transition

In March 2020, the UA mandated that all in-person courses transition to online courses due to concerns regarding COVID-19. As this transition was announced over spring break, the university extended spring break by two days to allow for faculty and students to prepare for this transition, with classes resuming on Wednesday, March 18. The Department of Mathematics chose to maintain a synchronous schedule for all courses that had taken place in-person. Additionally, the UA Department of Mathematics provided several days of voluntary trainings in various technologies to assist faculty with preparing for live online classes. The department also maintained an online communication platform for departmental questions and discussions regarding online instruction. Training sessions focused on topics such as Zoom for online class sessions (breakout rooms, participation, recordings, etc.); D2L (UA online platform for course information); resources for creating and sharing videos of class content; methods for proctoring online assessments; and methods for assigning and collecting written work. Additionally, the UA Office of Instruction & Assessment regularly offered workshops and trainings throughout the year for online teaching methods and resources. Once classes resumed, all math classes took place on Zoom. The free campus tutoring service was temporarily halted during the beginning of the transition to remote learning; once it began again, tutoring was offered by student tutors only. The departmental tutoring service was permanently closed after the transition.

After the transition

After the transition, UA math courses continued during the previously scheduled class times. Each class was recorded and made available for students who were unable to attend synchronously. The number of office hours did not generally change, although they were only available via Zoom. All assessments were given using an online homework platform or required students to upload images of written work. Many students no longer had access to their calculators and instead were asked to download an online calculator app to a smart device for use during assessments. The campus libraries remained available to students who needed to checkout tablets, laptops, or other devices. Although campus housing remained open, the dormitories were consolidated into several specific buildings, so many students moved residences even while remaining on campus.

As a result of remote learning, many students were expected to have access to technology that would allow them to attend class or watch material online. It was largely expected, although not required, that students would have a recording device (webcam, phone, or tablet) for the purpose of proctoring online exams. Reliable internet became a necessity for both class time and class work. To supplement class discussion and questions, some courses used additional platforms such as Piazza, Slack, Microsoft Teams, etc. Students with accommodations (such as extra time to take an exam) scheduled specific exam times with the instructor for their courses, rather than through the Disability Resource Center.

In acknowledgement of the extreme impact of this mid-semester transition and the continuing pandemic, the university allowed a one-time pass/fail option for any university course. A passing grade (P) is awarded for a grade of D or higher. For the Spring 2020 semester, if a student was not a math major, a passing grade (P) satisfied the grade requirements to advance to the next math course in their degree sequence. If the student was a math major, many courses still required a specific letter grade of C or higher to progress to the next math course in their degree sequence. As a university policy, final exams were still required. However, nearly all coordinated math courses adopted a final exam policy that the final exam could only improve a student's overall course grade.

3. Methodology

Measuring math anxiety

In 2003, Derek Hopko, Rajan Mahadevan, Robert L. Bare, and Melissa K. Hunt developed and validated the Abbreviated Math Anxiety Scale (AMAS) with a group of 1,239 undergraduate students at the University of Tennessee at Knoxville [12]. They found that their survey had high internal consistency and high retest reliability after two weeks when they re-surveyed the same group. The AMAS consists of 9 scenarios. Students are instructed to picture their level of anxiety in each situation and to rank their level of anxiety using a 5-point Likert scale, where 1 means low or no anxiety and 5 means high anxiety. A total anxiety score ranging from 9 to 45 is obtained by summing the participant's answers to the 9 items. The AMAS has previously been used to compare anxiety before and after a learning experience. For example, student teachers took the AMAS on the first and last day of their early childhood mathematics methods course [17] or took the AMAS before and after learning several self-regulated learning strategies [16]. The 9 items on the AMAS assessment can be divided into two sub-scales: Learning Mathematics Anxiety (LMA) and Mathematics Evaluation Anxiety (MEA). The LMA measures anxiety during math instruction or studying, and consists of items 1, 3, 6, 7, and 9. The MEA measures anxiety due to completing a math assessment and contains items 2, 4, 5, and 8. Brown, Ortiz-Padilla, & Soto-Varela showed that there is good internal consistency within each subscale [6].

Given that the transition was an emergency and highly unexpected, a retroactive assessment was the best practical model for our case. During the survey, we asked students to picture their level of anxiety in each of the AMAS situations before the transition and after the transition.

Table 1 describes the way we adapted AMAS to our needs. To the left is the original AMAS [12]. To the right is our adaptation. We modified wording slightly in some items to better describe UA circumstances.

Table 1: AMAS and our adaptation

Original AMAS

(i) Having to use the tables in the back of a math book.
(ii) Thinking about an upcoming math test 1 day before.
(iii) Watching a teacher work an algebraic equation on the blackboard.
(iv) Taking an examination in a math course.
(v) Being given a homework assignment of many difficult problems that is due the next class meeting.
(vi) Listening to a lecture in math class.
(vii) Listening to another student explain a math formula.
(viii) Being given a "pop" quiz in math class.
(ix) Starting a new chapter in a math book.

Our version of the AMAS

(i) Having to use a reference sheet with math formulas.
(ii) Thinking about an upcoming math test 1 day before.
(iii) Watching a teacher work an equation on the board.
(iv) Taking a math exam.
(v) Being given an assignment of many difficult problems due the next class meeting.
(vi) Listening to a lecture in math class.
(vii) Listening to another student explain a math concept.
(viii) Being given a "pop" quiz in math class.
(ix) Starting a new section in a math book.

Other Survey Items

We asked students to self-report information regarding their demographics, semester experiences, and technology access. Demographic questions asked students their gender, race/ethnicity, university level, and prior experience with online learning. Questions on student experience focused on class structure, communication formats (during class and outside of class), and assessments or grading. The survey also asked students to describe their experiences with financial stability, housing, and access to adequate academic resources (such as study space, technology, etc.).

To validate novel survey items, we presented a draft of the survey to 4 undergraduate students. Each student participated in a 30-45 min individual interview conducted by 1-2 researchers, and in compensation for their time, each received a $20 gift card to a well-known online shopping platform of their choice. To assess survey language and structure, we asked each student to describe their interpretation of the questions after reading the survey. We also asked if they thought there was another concern we should ask about. Based on these discussions, we included a survey question to assess student Zoom security concerns, e.g. privacy concerns surrounding Zoom recordings or concerns related to unauthorized users entering the meeting, informally known as Zoom-bombing.

Survey data collection

Our survey was hosted through Qualtrics. Following IRB approval, we used a departmental listing to invite all students who took an undergraduate mathematics course (100 - 400 level) at the University of Arizona main campus in Spring 2020 to participate. Survey respondents received no compensation for their participation. Participants completed the survey mid-Summer 2020 and were asked only to assess their math course experiences from Spring 2020. We invited 6,761 students to participate and 891 took the survey, giving us a response rate of slightly more than 13%.

Data cleaning and pre-transition AMAS score validation

While 891 students responded to the survey, we only used the data from 834 students because they completed all of the 9 items in the AMAS twice, one response representing their pre-transition anxiety and one response for their post-transition anxiety. (We needed a numerical value for each of the 18 items in order to calculate a pre-transition math anxiety score and a post-transition math anxiety score.)

The average pre-transition anxiety score of the 834 students we surveyed was M = 22.02 (SD = 6.89). To validate our measured pre-transition anxiety scores, we compared our data to known score averages from comparable undergraduate populations. We collected the following AMAS data from published studies involving undergraduate students attending a university in the United States (as would be comparable to the University of Arizona according to the *US News and World Report* categories "National Universities" and "Regional Universities" [21]). The weighted (according to sample size N) average across these six studies (shown in Table 2) is 21.68 points. The similarity of the collected averages and our observed survey average indicated that our data was reasonable.

Table 2: Validation of our average math anxiety score via a weighted average

Established averages for AMAS score				
Student Body Description	Sample	Ave. Score	Deviation	Study
University of Tennessee	N = 1,239	M = 21.1	SD = 7.0	[12]
University of Tennessee	N = 80	M = 21.5	SD = 5.5	[13]
University of Tennessee	N = 100	M = 21.8	SD = 5.2	[14]
Urban northeast univ.	N = 29	M = 19.83	SD = 6.48	[16]
State universities: 1 southeast, 1 northeast	N = 234	M = 22.90	SD = 5.7	[15]
Large Midwestern univ.	N = 144	M = 25.09	SD = 6.74	[22]

4. Results

We conducted our statistical analysis using a combination of SPSS (version 27) 2020 and R (version 4.0.0) 2020. Figure 1 shows the distribution of the AMAS scores both before and after the transition. Notice that after the transition AMAS totals are shifted towards higher anxiety with significantly more spread than the corresponding data before the transition. Following a simple difference calculation, Figure 2 shows the distribution of the change in AMAS total scores.

The data show that we had three subgroups of students: those who experienced an anxiety decrease ($\sim$ 20% of respondents), those who experienced no change in anxiety ($\sim$ 15% of respondents), and those who experienced an increase in math anxiety ($\sim$ 64% of respondents). The majority of students that experienced no net change in anxiety score reported no change in anxiety item by item in the AMAS. However 19 of the students that had no net change in anxiety (approximately 15% of the no net anxiety change students) had a score increase in at least 1 item and a corresponding score decrease in at least 1 item. Finally, we note that our data is not normally distributed. As such, we utilize the appropriate nonparametric statistical tests throughout our analysis.

A Wilcoxon test was performed to see if there was a difference between each student's anxiety score before the transition and their anxiety score after the transition. With statistical significance, the two scores were different with an average increase in anxiety score of M = 4.69, SD = 7.89 (Z = -15.850, $p < .001$). Furthermore, a Wilcoxon test was performed to assess statistical

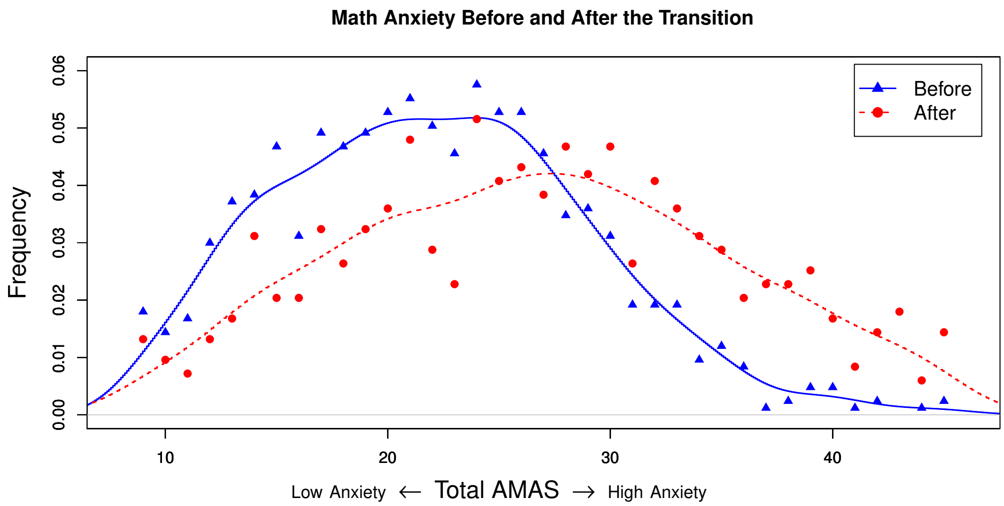

Figure 1: Distributions of the AMAS total scores are shown. Each triangle a gives the frequency of an AMAS score before the transition, while the blue curve is the corresponding frequency distribution function. Each circle gives the frequency of an AMAS total score after the transition, while the dashed red curve is the corresponding frequency distribution function.

significance in comparing each student's average change in anxiety score for a learning (LMA) item and their average change in anxiety score for an evaluation (MEA) item. The two scores differed with statistical significance (Z = -2.26, p = .024). On average, students experienced a score increase of 0.55 per each learning item (SD = 0.88) and an increase of 0.48 points per each evaluation item (SD = 1.03). For context, the maximum possible increase in score per item is 4 points. Thus, while the difference in average increase between the learning and evaluation items is statistically significant, the difference is not impactful. The increase in math anxiety was roughly equivalent in the LMA and MEA subscales.

Determining effect size

The AMAS assigns each student an anxiety score of 9 to 45 points. Maloney, Risko, Ansari, & Fugelsang [19] explain that an AMAS score from 9 to 19 points indicates low math anxiety, while a score ranging from 31 to 45 points indicates high math anxiety. Computing the length of these intervals, we find that an increase of 11 points guarantees a low math anxiety student now

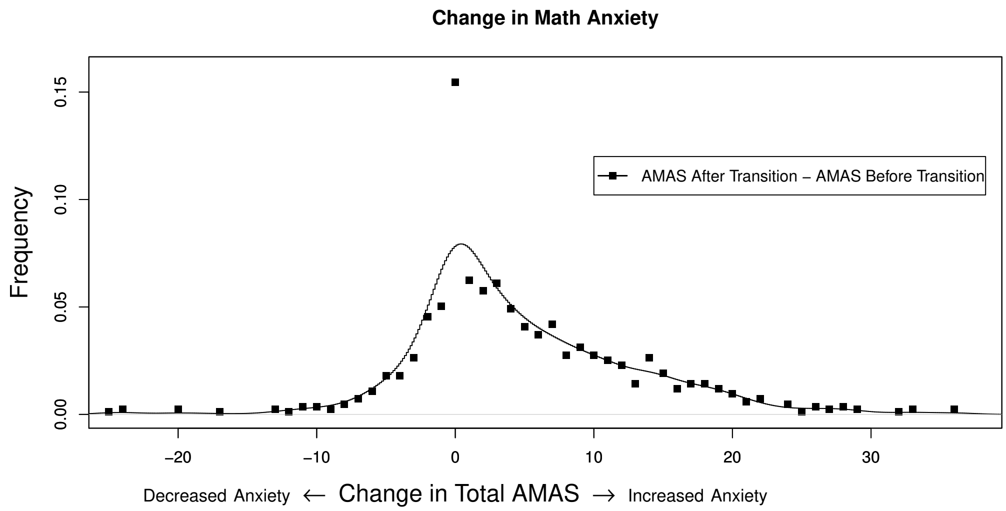

Figure 2: The frequency of the change in AMAS scores, from before the transition to after the transition, is indicated by the points, together with the corresponding density function. Note that 129 respondents indicated no change in total AMAS score, with 110 respondents indicating no change item by item.

experiences medium math anxiety and an increase of 12 points guarantees a medium math anxiety student now experiences high math anxiety. In fact, in our data we found that the average increase in anxiety score among students who went up a level in anxiety (i.e. low to medium or medium to high) was M = 10.20 (SD = 4.753). Accordingly, we consider any subgroup that experiences an average anxiety increase greater than 10 to be at high risk of increasing their anxiety level. Among the students whose anxiety level did not change, the average anxiety score increase was M = 1.07 (SD = 3.181). Thus, we consider any subgroup that experiences an average anxiety increase less than 1 point to be at low or no risk of increasing their math anxiety level. This impact scale is shown in Table 3.

Table 3: Defining high and low impact

Impact of change in anxiety score	
$\geq$ 10 points	High impact
$\leq$ 1 point	Low/No impact

High impact trends

We will begin our report with these high impact trends, which fall into two categories: technology and communication. A Kruskal-Wallis test was conducted for the six questions concerning access to and quality of technology. The results can be found in Table 4.

Table 4: High Impact Trends: Access to Technology

High Impact: Access to Technology				
Question	K-W H, p value	Response	n	Δ Anxiety (SD)
Internet Access	$H(2) = 26.024$, $p < .001$	Most of the time	701	4.07 (7.604)
		About half the time	108	7.70 (7.852)
		Rarely had access	18	**11.11** (11.975)
Webcam Access	$H(2) = 111.317$, $p = .003$	Most of the time	737	4.37 (7.737)
		About half the time	53	7.42 (7.210)
		Rarely had access	37	7.84 (10.631)
Computer Access	$H(2) = 9.655$, $p = .008$	Most of the time	791	4.52 (7.739)
		About half the time	32	7.56 (9.363)
		Rarely had access	5	**16.80** (12.558)
Quality of Internet	$H(2) = 35.153$, $p < .001$	Most of the time	538	3.58 (7.474)
		About half the time	230	6.41 (7.844)
		Rarely had access	58	8.05 (8.955)
Quality of Webcam	$H(2) = 15.786$, $p < .001$	Most of the time	692	4.22 (7.533)
		About half the time	90	7.47 (8.110)
		Rarely had access	40	8.00 (10.488)
Quality of Computer	$H(2) = 17.991$, $p < .001$	Most of the time	727	4.24 (7.563)
		About half the time	85	8.22 (8.985)
		Rarely had access	13	9.85 (11.929)

Note. The 'Question' column gives the question we are considering. K-W H stands for the Kruskal-Wallis H. The 'Response' column lists possible answers (most of the time, about half the time, and rarely had access), and n is the number of respondents from said category. The final column is the average reported change in anxiety score, with the standard deviation following it in parentheses. Averages which meet the high impact threshold appear in bold.

Note that students with rare access to the internet and students with rare access to a computer were at high risk of increased math anxiety. Quality of computer did not quite meet our threshold for high impact, but the average increase in anxiety is close to 10 points and issues of quality should also be considered important.

We also wish to draw attention to the number of respondents in the high impact categories. While the anxiety increases with respect to technology were extremely large, there were relatively few individuals that experienced this level of increase. There is a potential for under representation in this category, however we will elaborate more on this in Section 5. A much larger proportion of students indicated the importance of instructor communication and quality of feedback.

A Kruskal-Wallis test was conducted for the 3 questions concerning communication with a math instructor. The results can be found in Table 5.

Table 5: High Impact Trends: Communication with Instructor

High Impact: Communication with Instructor				
Question	K-W H, p value	Response	n	Mean Δ Anxiety (SD)
Was Instructor Available for Communication	$H(2) = 111.22$ $p < .001$	Yes	535	2.64 (6.658)
		Neutral	175	7.30 (8.324)
		No	114	**10.40** (8.798)
Comfort of Communication With Instructor	$H(2) = 136.99$ $p < .001$	Comfortable	427	1.92 (6.137)
		Neutral	193	5.47 (7.641)
		Uncomfortable	202	9.95 (8.703)
Difference in Quality of Feedback After the Transition	$H(2) = 105.25$ $p < .001$	Improved†	38	-1.18 (7.139)
		Consistent	549	3.23 (6.650)
		Declined	234	9.16 (8.831)

Note: Column labels are consistent with Table 4 above, with the note that subgroup is the only appearance of reduced anxiety (as evidenced by this average being negative).

Students who felt that their instructor was not available for communication are at high risk of increased math anxiety. Discomfort with communicating with the instructor and a decline in quality of feedback on assignments did not meet our threshold for high impact, but the average increases in anxiety are very close to 10 points.

Other trends

The groups in this subsection did not have an average increase anxiety within the "at high risk" threshold of 10 points. A Kruskal-Wallis test was performed based on whether students had less, more, or the same amount of quiet time and space for school work after the transition. The Kruskal-Wallis was also used to distinguish differences in anxiety between students in 100-level courses, 200-level, or 300- and higher level courses. While students in 100-level courses on average experienced a greater increase in math anxiety than students in 200-level courses, the difference is by less than 1 point. A Mann-Whitney test was performed based on students' stability of financial situation (stable or unstable), concern about Zoom-Bombing (yes or no), and moving mid-semester (yes or no), see Table 6.

The final groups we considered were based on gender. Among the 6761 undergraduate students who took a Spring 2020 mathematics course at the University of Arizona (i.e. our sampling frame), 52.3% were male, 47.7% were female, and less than 0.1% were another gender. Our sample contained 483 (40.4% of our sample) students who shared that they were female and 337 (57.9% of our sample) students who shared that they were male. The other 14 students either chose not to share their gender or are non-binary/third gender. Because these 14 students form such a small pool within the total sample population, we did not include them in our statistical analysis. A Mann-Whitney test was performed to discern any differences in average change in anxiety between male and female students, see Table 6.

Table 6: Other Statistically Significant Trends

Other Trends

Question	K-W H, p value	Response	n	Δ Anxiety (SD)
Availability of Quiet Time & Space After the Transition	$H(2) = 80.101$ $p < .001$	Less	505	6.34 (8.145)
		Same	213	2.10 (6.343)
		More	111	1.75 (6.856)
Course Level	$H(2) = 13.568$, $p = .001$	100-level	448	5.31 (8.1131)
		200-level	210	4.60 (7.850)
		300- or 400-level	164	3.06 (7.072)

Question	M-W U, p value	Response	n	Δ Anxiety (SD)
Stability of 2020 Financial Situation	$U = 42750.50$ $z = -5.40, p < .001$	Stable	511	3.55 (6.88)
		Unstable	223	7.21 (9.65)
Concerned About 'Zoom-Bombing'	$U = 31473.50$ $z = -3.23, p = .001$	Yes	109	6.73 (9.103)
		No	714	4.34 (7.632)
Did You Move Mid-semester	$U = 68373.00$ $z = -2.44, p = .015$	Yes	561	5.12 (8.03)
		No	272	3.78 (7.54)
Gender	$U = 71339.50$ $z = -3.02, p = .003$	Female	483	5.35 (8.18)
		Male	337	3.81 (7.53)

Note. Column labels are consistent with Table 4 above. K-W H stands for the Kruskal-Wallis H. M-W U stands for the Mann-Whitney U statistic. In the 'Finding Quiet Time & Space' rows, we are comparing the availability before vs after, therefore 'Less' time indicates a loss of quiet time and space after the transition.

Data that were not statistically significant

For the sake of completeness, in this subsection we briefly share other questions that yielded no results. There were 86 participants that reported they had experience with an online college math class, ranging from online synchronous or online asynchronous to a hybrid course model, prior to Spring 2020. There was no statistically significant difference between those with online learning experience and those without. Similarly, having an online discussion forum for the class made no statistically significant difference in math anxiety during the transition. (Survey results showed that 364 students had a discussion forum in their math class, while 444 students did not.)

Our data did not show any statistically significant difference in change in anxiety between any one ethnicity/race group and the rest of the respondents (see Table 7 for these ratios), or between students grouped based on the number of years they had attended the University of Arizona. However, within our particular data set, on average, first year students experienced an increase of 3.12 points greater than students with 4+ years of experience at the university.

Table 7: Ethnicity and Race of Survey Respondents

Demographics	
Ethnicity/Race	n
American Indian or Alaska Native	17
Asian	124
Black or African American	29
Hispanic or Latinx	222
International	30
Native Hawaiian or Other Pacific Islander	7
White	533
Other	9

Note. Table 7 shows the number of respondents that reported each indicated ethnic background. Note that respondents could indicate multiple ethnic/racial backgrounds.

We analyzed the difference in anxiety change between students living within 3 time zones of the university (located in Tucson, AZ) and students who were taking classes at greater than 3 times zones away. We had 51 students report that they fell outside the ± 3 time zones while 443 reported that they were within this range. We found no statistically significant difference in change in anxiety between these two groups.

Students' Impressions of the Transition

The final trend we considered is likely an example of the old statistics adage correlation does not imply causation, however it is worth mentioning because it provides a snapshot of how students felt. We asked students if they agree with the statement "my transition to remote learning went as well as it could have, based on the COVID-19 emergency". A Kruskal-Wallis test was performed to detect differences in anxiety change between those who somewhat or strongly disagreed with this statement, neither agreed or disagreed, and those who somewhat or strongly agreed, see Table 8.

Table 8: Students' Impression of the Transition

Impressions				
Question	K-W H, p value	Response	n	Δ Anxiety (SD)
Transition went as well as possible	$H(2) = 150.635$ $p < .001$	Disagree	252	9.65 (8.594)
		Neutral	80	5.63 (7.254)
		Agree	501	2.05 (6.241)

Note. Column labels in Table 8 are consistent with Table 4 above.

On average students who disagreed experienced a 7.593 point greater change in their anxiety over students who agreed.

5. Discussion

Technology

We had relatively few respondents report that they had rare access to the internet or to a computer, see Table 4. However, we can see that these few individuals experienced a much greater increase in anxiety than their counterparts who had reliable access to the needed technology and resources. Further, the ability to attend class does not completely assuage mathematics anxiety; quality of technology is instrumental in learning. Overall, Table 4 shows the great importance of campus technology services that provide students regular access to quality technology, such as laptop rentals, in reducing mathematics anxiety during an emergency remote class. Note that limited access to a webcam was less of an indicator of increased anxiety for students. One possible explanation is that at no point was a student required to be on camera in the Spring 2020 semester. Exams typically required students to have a webcam, but students without webcams were not penalized as long as they informed their instructor.

While American Indian or Alaska Native students only comprised $\sim 2\%$ of our overall response pool, these students made up $\sim 17\%$ of the students who rarely had access to the internet after the emergency remote transition. When asked how aspects of life outside of school affected their experiences in math class after the transition to remote learning, one student wrote:

> "I live on a Native American Reservation. My math instructor showed no understandment [sic] at all. Where I live we have curfew from 8 PM to 5 AM and 57 hour lockdowns. Which GREATLY limited my access to my education."

Some native students had to move out of the University of Arizona dorms and return to their tribal land during the transition. We do want to acknowledge that the University of Arizona, as a land-grant institution, prioritized educational access for Arizona communities. In response to the transition in the Spring 2020 semester, University of Arizona provided remote wireless hotspots across the state of Arizona that could be accessed by driving up and using the wireless from inside a vehicle. There were 15 hotspot locations outside of Tucson, including some in Navajo Nation and San Carlos Apache Indian Reservation.

Finally, it is important to address all technology access problems, not just a single concern. Two of the five students who reported rarely having access to a computer also reported rarely having access to the internet. Such a student may not experience any less anxiety if only one of these two challenges was fixed. With this in mind, we should, at minimum, strive for counteracting both of these anxiety increasing items. Considering access to quality computers and internet connections together, even improving from rare access to about half the time access, can yield substantial decrease in math anxiety.

Communication

Communication, or lack thereof, also played a significant role in how much a student's anxiety changed during the transition to remote learning. In surveying the students, we made a key distinction between whether an instructor was available, even if a student did not take advantage of that availability, and whether a student felt comfortable approaching the instructor. We found an increase in anxiety of 7.759 points in students who reported that they did not have good access to their instructors compared to those that said they did. Thus, the availability of the instructor to answer questions, either during or outside of class, played a significant role in how students perceived their anxiety. To compound with the availability of the instructor, we found an increase of 8.025 points in students who did not feel comfortable approaching their instructor over those that did feel comfortable interacting with the instructor.

While we wish there were a quick and easy fix to establishing open lines of communication, each teacher needs to find what works for their teaching style within their classroom. For example, our results showed that simply having a class discussion board was insufficient to improve student anxiety outcomes. The advice we would give teachers comes from previous work in the area of anxiety reduction. Since negative experiences in math classrooms have been linked to the origins of math anxiety, teachers should be careful to avoid hostility towards or embarrassing any student experiencing mathematical difficulties. In addition to monitoring their own responses, teachers should not allow students to engage in this behavior either [24]. In fact, it is vital that teachers support students by making them feel comfortable and encouraging them to ask for help whenever they need it [2]. This is reinforced by our study, as comfort level communicating with instructor is shown to have a significant impact on math anxiety.

Furthermore, our results showed the importance of quality feedback for students. When considering assessment, teachers can help in preventing student frustration by establishing clear, progressive, and feasible goals. Teachers should highlight the importance of mathematics, provide positive feedback where appropriate, and minimize the importance of errors [24]. All the while, teachers should encourage students to embrace the idea that working hard on math is the only way to succeed, especially since hard work does not depend on any special mathematical gifts.

Gender

The extent to which gender is related to math anxiety has been widely studied with varying results. However, the majority of studies find that there is a gender difference, with women reporting higher levels of anxiety than men [1, 7, 8, 10, 11, 20]. There is strong evidence which suggests that the

AMAS is invariant across gender [27], so we must look deeper. It is theorized that gender differences in math anxiety are a consequence of socialization [4]. While findings such as ours may be representative of an actual gender difference, these findings may be more a function of societal factors that increase the willingness of female students to self-report anxiety symptoms. This relationship merits further study as evidence suggests that female students are more prone to avoid not only mathematics courses but also careers that requires mathematical skills [12].

Limitations

When considering these results, we should bear in mind some potential limitations in survey format as well as specific question structure. In terms of the survey instrument, several features might be improved in a future study. We asked students for retroactive self-assessments, which, by their nature, are less reliable than a current self-assessment. We note, however, that our pre-transition results align well with similar universities, as seen in Table 2. This leads us to believe that any potential discrepancies between reality and the retroactive self-assessment are minimal, if they exist. Further, our survey also asked students to only consider a single mathematics course they took over Spring 2020, without identifying the course itself. This choice was made to ensure the confidentiality of respondents, but the omission of course number did cause a lack of finer details concerning students' individual experiences in multiple courses.

Finally, the survey submission format is also worth re-examining for future studies. Survey questions were only available online (via an emailed link), which naturally creates bias against obtaining responses for individuals who had low access and/or low quality technology tools, such as an internet connection. Moreover, the survey was available in English only, and hence we may have fewer responses from individuals due to language barriers or disabilities. Thus, while our high impact results in said areas have very few respondents, this may not be an accurate representation of the true number of students who encountered these problems. Therefore, it is important to take this issue seriously even though these results may indicate that the problem only applies to an extreme minority.

Future Research

The following directions merit further exploration.

- Explore the extra challenges posed by disabilities, such as disabilities with language processing and hearing or visual impairment, in the emergency remote learning environment. In an emergency, many of the once readily available disability resources are no longer available to students. Additionally, new unanticipated challenges may arise.
- Examine the role of language barriers in remote learning outcomes for students.
- There is a potential for online education to decrease math anxiety for some students. What aspects of the online environment can alleviate anxiety? What students benefit from the online environment?
- Because access to technology was so vital during the emergency transition, we should explore the utilization and effectiveness of short-term technology rentals as well as community internet hot spots.

6. Conclusion

Localized emergency remote learning will continue to be a likely possibility due to natural disasters or public health emergencies. Nonetheless, our survey data from the mid-semester transition of the COVID-19 pandemic shows that students are resilient. The majority of students indicated that the transition to remote learning went as well as it could have, based on the COVID-19 emergency. Moving mid-semester or facing instability in finances had some impact, but the data shows that factors with greatest impact are immediately actionable. Factors that directly impacted a student's learning experience with a high impact on changes in math anxiety include communication with the instructor as well as technology quality and access. Giving extra support to students in these two areas may result in the greatest reductions in math anxiety. Ultimately, understanding the effects of current policy can help academia better serve students in future emergencies.

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