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Effects of an Intensive Mathematics Course on Freshmen Engineering Students' Mathematics Anxiety Perceptions

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Introduction

The development of a country is normally connected to its ability to train a sufficient number of engineers to be able to develop technological solutions to their national problems[1]. Engineers' insight and designs help solve problems that affect all of humanity such as access to food and safe drinking water, communication, health care, and environment protection [2]. There are both personal and national benefits to pursuing a degree in engineering; however, engineering training and education both rely heavily on students' math abilities. Students' math preparation and attitudes toward math-related activities have shown to be significant factors in students' decision to pursue an engineering major [3–5]. Students' development of math knowledge before college is commonly influenced by their experiences in math courses, where their experiences create different feelings about math activities. An important factor influencing students' perceptions about math courses and activities is math anxiety. Richardson & Suinn[6] defined math anxiety as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic settings" (p. 551). Math anxiety is not just dislike of mathematics or lack of math knowledge, but a set of feelings that affect performance in math-related activities that may lead to avoidance of math courses and math-related careers [7].

Mathematics anxiety can originate in many different ways, and it is typically linked to perceptions of low math ability, prior unsuccessful experiences, and lack of studying and poor test preparation skills [8]. High math anxiety has shown to be a significant predictor of poor math performance, and is also negatively correlated with the decision of pursuing a mathematics-related major [9]. Also math anxiety has been found to be greater for students with poor performance in math achievement tests [10,11]. Research has shown that students with high anxiety levels are usually concerned with the possibility of performing poorly and failing school courses; failing any course in school is seen by these students as a problem that will bring consequences in their academic development [12].

Math anxiety levels are usually influenced by the importance that students attribute to math activities, especially if they consider math as an important aspect of their academic and professional development [13]. If a student considers math skills to be important for success in their major, they may be more likely to experience stress and feelings of anxiety when performing math activities, especially if they experience struggles in their learning process [14]. Math anxiety feelings have shown to vary according to students' grade-level in school; lower grade-level courses have shown to produce less math anxiety on students than upper grade-level courses [13]. Math anxiety usually grows as students move forward in their education and learn more advanced math topics. Feelings of math anxiety usually become more established and constant once students get to their junior and senior high school years [15]. College students frequently report higher math anxiety levels than high school students. These feelings of anxiety are typically greater for students with fewer math courses taken at the high school level than for students with more experience with math courses before college [11].

Although men and women students seem to place equal importance on math, women have shown to be more likely to report feelings of stress and anxiety when they perform math activities [11]. These anxiety feelings could be negatively influencing women in their decision to continue taking math courses, especially when the math courses are no longer required by their schools [10]. When students decide to stop taking math courses early in their precollege preparation, they may be inadvertently aggravating their math anxiety feelings. Students' anxiety feelings when performing math activities have been shown to be stronger when these students are less experienced in math, are taking fewer math courses, and are less involved in math activities [11].

Although students' math performance and intentions to continue taking math courses are related to students' math anxiety levels, the effects of math anxiety have shown to lose significance and be indirectly related to these two factors when other variables like previous performance, general attitudes towards math, and self-concepts of math ability are also examined [10,14]. According to Bandura[16], math anxiety has an inverse relation to self-efficacy levels. Thus, increasing math self-efficacy may decrease students' feelings of anxiety when they perform math activities [17].

There is some ambiguity concerning the possible effects of math anxiety on students, and this ambiguity is normally generated by the different ways by which math anxiety is measured. For example, including survey items and questions that could combine students' perceptions of their math abilities with their feelings about performing math tasks can create ambiguity [13]. If math anxiety is not established and measured as an independent factor, developing a conclusion about its effects on students' behavior and attitudes towards math activities becomes a challenging task. However, it is important to recognize that math self-efficacy is related to math anxiety, and that these two factors are normally influenced by the same past experiences [18]. Wigfield and Meece[13] found that students' math anxiety was more than just lack of confidence in their math abilities; rather, this math anxiety was centered in the negative affective reactions that these students experience when they perform or think of performing math activities. This suggests that math interventions that are focused on improving students' math self-efficacy alone are not enough to ameliorate these students' feelings of stress and anxiety when performing mathematical tasks. In addition to boosting students' confidence about their math abilities, students with high math anxiety will also need training focused on reducing their fear and dread about performing math activities.

This research aims to deepen our understanding of how engineering students experience math anxiety by addressing the following research question: How do feelings of math anxiety change after an intensive four-week math intervention, and what kind of factors could affect students' math anxiety feelings?

Methods

Participants for this quantitative study were selected from a northern Mexican university for only engineering majors. To be accepted in this university, students must first take the university's selection test; if students score a satisfactory grade on their selection test then they are conditionally accepted. To complete their selection process and be considered fully accepted, students must pass a four-week summer math course designed to standardize their math

knowledge with a grade of 70% or better. Students meet 5 times a week for 2 hours at this math course, which is a review of basic math knowledge that students should have acquired in high school (arithmetic, algebra, trigonometry and geometry). The course pace is faster than a normal class because it is considered to be a review. Students are evaluated once a week, completing 3 weekly tests and a final cumulative test at the end of the fourth week.

All conditionally accepted students for the Fall 2015 semester taking the math course (N=809) completed a math anxiety survey with 20 Likert-type items (with scores from 1 "not anxious at all" to 5 "very anxious") on the first and last days of the four week course. The survey was distributed during class time just before a test. The first survey distribution was the very first day of the course, before a diagnostic test (which is not part of the final grade). The final survey was distributed the last day of the course, right before the final test. Twenty items from a validated math anxiety survey, the 30-item Mathematics Anxiety Rating Scale (MARS 30-item)[9], were selected based on relevance to the context in the Mexican university. The survey was structured around math problems that students were likely to encounter in school or daily life, which students then had to rate in terms of their level of anxiety when solving. An example of an item that was deleted from the survey for this population is one related to calculating tax on a purchased item; in Mexico, students would not encounter such a problem because tax is included in the price of items, not calculated separately. The twenty remaining survey items were translated from English to Spanish by an expert in the field who is fluent in both languages. A few minor wording changes were made based on the difference between the American and Mexican university contexts. The survey included 52 additional items measuring students' math self-efficacy, which are not relevant for this particular paper.

Survey reliability was tested for this population with an exploratory factor analysis (EFA), and two different constructs were found. Three items that did not load on either of the two constructs were removed from the data. A confirmatory factor analysis was performed on the remaining 17 items to confirm the two constructs found with the EFA. For data analysis, an average of the items was calculated as a general math anxiety score (between 1 and 5). Average scores for items within each of the two constructs were calculated for each participant, and statistical analyses were conducted to determine if there were differences between scores. T-tests were conducted to determine differences between math anxiety levels for students with different backgrounds and for differences between the beginning and end of the course. The data were also analyzed for possible differences in the math anxiety levels for students of different genders, high schools (private, technical, art and humanities, and rural), and states of origin (city/town and out of town/state). Additional T-tests were conducted to determine what factors could affect students' math anxiety levels during the math course depending on gender and background.

Results

The EFA showed that items loaded into two different constructs: math test anxiety and math activities anxiety. These two constructs were similar to those found in prior studies using the same survey items in different contexts [9]. Three items were removed before continuing with the data analysis due to low loadings (< 0.4) on either of the two empirically found constructs. The two constructs found with the EFA were math test anxiety (9 items) and math activities anxiety

(8 items). The items loaded on the two suggested constructs with loading factors above 0.5, confirming the reliability of the survey with this population. Additionally, Cronbach's alpha (α) calculated for the math test anxiety and math activities anxiety constructs using the 17 remaining items were $\alpha = 0.84$ and $\alpha = 0.87$ respectively, demonstrating a good internal reliability consistency of the survey constructs.

The average math anxiety that students reported was relatively low, with an average of 2.37 for the pre-course survey and 2.69 for the post-course survey. Data analysis showed that across gender, type of high school, and students' origin, students' math anxiety levels increased significantly after the four week course for both math test anxiety and math activities anxiety (see Tables 1 and 2). The math test anxiety construct average was significantly higher than the math activities anxiety average in all groups, showing that a majority of the stress produced by math courses is based on the anxiety that math tests produce. The only group of students that did not show a significant increase in their math anxiety levels was the rural high school students.

Table 1. Math anxiety mean values for the pre and post comparison of overall survey and individual construct scores.

	Pre-course	Post-course	P-value
All students	2.377	2.694	< 0.001
- **Math test anxiety**	2.771	3.179	< 0.001
- **Math activities anxiety**	1.932	2.167	< 0.001
Private high school	2.249	2.528	< 0.01
- **Math test anxiety**	2.569	2.989	< 0.001
- **Math activities anxiety**	1.888	2.011	NS
Technical high school	2.379	2.677	< 0.001
- **Math test anxiety**	2.804	3.161	< 0.001
- **Math activities anxiety**	1.901	2.133	< 0.001
Art and humanities high school	2.397	2.898	< 0.001
- **Math test anxiety**	2.794	3.370	< 0.001
- **Math activities anxiety**	1.949	2.366	< 0.001
Rural high school	2.498	2.634	NS
- **Math test anxiety**	2.846	3.108	NS
- **Math activities anxiety**	2.106	2.101	NS
City/town students	2.346	2.711	< 0.001
- **Math test anxiety**	2.745	3.195	< 0.001
- **Math activities anxiety**	1.898	2.166	< 0.001
Out of town/state students	2.467	2.680	< 0.01
- **Math test anxiety**	2.849	3.132	< 0.01
- **Math activities anxiety**	2.038	2.171	NS

The math anxiety increase was significant for both male and female students, but effects on female students were stronger, especially in the post course measurements (see Table 2). Female students showed higher math anxiety than males before the course, and their anxiety levels increased significantly after the course. This increase in math anxiety could be related to the fast pace of the course, or the pressure to pass the course to be accepted in the university. Females' anxiety averages on the math activities construct showed an increase in the post-course measurement, but this increase was very similar to the one that male students had. Performing math-related activities was the only anxiety construct where males and females did not show a significant statistical difference for most categories, even after increasing their general math anxiety level after the four-week course.

Table 2. Math anxiety mean values pre-course and post-course for male and female students comparing overall survey and individual construct scores.

		Anxiety type	Male	Female	P-value
All students	**Pre-course**	- overall	2.339	2.444	< 0.05
		- math test	2.688	2.919	< 0.001
		- math activities	1.938	1.922	NS
	Post-course	- overall	2.596	2.865	< 0.001
		- math test	3.017	3.424	< 0.001
		- math activities	2.122	2.236	NS
Private high school	**Pre-course**	- overall	2.148	2.379	NS
		- math test	2.425	2.755	.05
		- math activities	1.836	1.955	NS
	Post-course	- overall	2.281	2.841	< 0.001
		- math test	2.717	3.333	< 0 .001
		- math activities	1.791	2.288	< 0.001
Technological high school	**Pre-course**	- overall	2.343	2.467	NS
		- math test	2.724	3.000	< 0.01
		- math activities	1.914	1.868	NS
	Post-course	- overall	2.632	2.760	NS
		- math test	3.050	3.366	< 0.01
		- math activities	2.163	2.078	NS
Art and humanities high school	**Pre-course**	- overall	2.387	2.411	NS
		- math test	2.735	2.882	NS
		- math activities	1.995	1.880	NS
	Post-course	- overall	2.763	3.075	< 0.01
		- math test	3.179	3.622	< 0.001
		- math activities	2.295	2.460	NS
Rural high school	**Pre-course**	- overall	2.402	2.628	NS
		- math test	2.713	3.027	NS
		- math activities	2.052	2.178	NS
	Post-course	- overall	2.453	2.807	NS
		- math test	2.894	3.313	NS
		- math activities	1.958	2.238	NS
City/town students	**Pre-course**	- overall	2.309	2.414	NS
		- math test	2.659	2.900	< 0.001
		- math activities	1.915	1.867	NS
	Post-course	- overall	2.615	2.864	< 0.001
		- math test	3.052	3.423	< 0.001
		- math activities	2.123	2.235	NS
Out of town/state Students	**Pre-course**	- overall	2.415	2.559	NS
		- math test	2.775	2.978	NS
		- math activities	2.010	2.087	NS
	Post-course	- overall	2.535	2.867	< 0.01
		- math test	2.906	3.425	< 0.001
		- math activities	2.117	2.240	NS

Discussion

The increase of students' math anxiety after the four-week course was significant for most categories of students. This increase in math anxiety suggests that this type of intensive, fast paced remedial courses could help students refresh their math knowledge; but at the same time, these courses could increase students' math anxiety levels, making students' more likely to decide to avoid math-related activities both in school and outside school environments. If math activities make students feel tense and anxious, then these students could develop negative affective reactions performing math that may lead them to lack of interest in math activities and poor math performance [17]. The only group of students that did not show a significant increase on their math anxiety was the rural high school group; there was no significant difference between

math anxiety averages of male and female students in this group either. More research about this finding should be performed to understand how the approach that rural high schools use to teach math to prepare their students to cope with the math anxiety potentially generated by this fast paced remedial course.

Understanding more about the effects of this type of fast paced remedial math courses will help math educators to better design these courses. The main focus of this type of course should be on enhancing students' math knowledge without creating a stressful environment that could develop math anxiety feelings during the process. The emphasis of this course on obtaining a passing grade of 70 or better to be accepted to the university, and the way assessments are conducted may have created a stressful environment in addition to the high stakes involved with passing the class. This stress about the assessments could be seen through the consistently higher averages of math test anxiety constructs compared to the math activities constructs for all categories of students, as shown in Tables 1 and 2. Math and engineering educators should consider the stress and anxiety that students may develop during assessments and when trying to obtain good grades. Frequent assessments may create a stressful environment for students who may need more time to practice and improve their math skills to feel confident enough to be evaluated. Findings suggest that math instructors should be prepared to support students and create a class environment that promotes students' learning, confidence in their math abilities, and development of tools to manage their stress while performing math. Failing to develop any of these factors could lead students to develop negative affective feelings about math, making these students less likely to get interested in math activities that could facilitate their math knowledge development.

Female engineering students reported a higher math anxiety than their male peers, which was expected based on current literature [11]. Female students in this study were shown to be more affected by the math anxiety in general. The course affected the math test anxiety average of female students based on high post-course scores. The literature suggests that because of high math test anxiety, female students may be more likely to have low confidence in their math abilities and get stressed thinking about the possibility of failing a test [18]. Male students are shown to have more confidence in their math abilities and ability to perform well on math tests [4]. This lack of confidence and higher math anxiety levels for female students may create negative feelings about math activities, making female students less likely to take advanced math courses or get involved in math activities that may help them to improve their math abilities. The level of anxiety that students reported for performing math in their daily activities did not show a statistically significant difference between male and female students for most groups, and it was overall lower than math test anxiety. This suggests that math activities are not seen as stressful tasks when they are part of students' normal daily activities where their performance is not assessed. Math educators should try to take advantage of students' lower math anxiety levels performing math activities to start developing students' confidence in their math abilities. If students' confidence in their math abilities is high enough, math educators should focus on the development of skills that help students to better manage and control their math test anxiety. Failing to help students manage math test anxiety could result in a perception of a high general math anxiety that may push students away from math courses and activities.

Conclusions

Our study found that there were significant increases in math anxiety from before to after an intensive four-week math review course for undergraduate engineering students at a Mexican university. This was especially prevalent specifically for math test anxiety; only one category of students (those who attended a private high school) experienced increased math activities anxiety. It is also interesting to note that in almost all categories of students (based on academic background and state of origin), females experienced higher levels of math test anxiety than males, but not higher levels of math activities anxiety.

Math educators should be aware of the importance of designing math courses with the goal of improving students' math knowledge without creating a stressful environment, especially stress related to math tests. If a math course creates and increases feelings of anxiety in students, then these students could be more likely to avoid math related activities and courses in the future; this could lead students to struggle in completing the challenging math curricula that engineering majors require.

Limitations and Future Work

Both math anxiety measurements were completed by students just before they took a math test. This may have influenced students' feelings about math, especially the math test anxiety construct. Feelings about taking a math test may have changed in a different context, but this was the only time available to distribute the survey for this course. Data was also collected about students' math self-efficacy as well. The math self-efficacy data will be used in a future study to test the inverse relationship between these two factors (anxiety and self-efficacy) shown in prior studies[8,18]. Analyzing math anxiety together with math self-efficacy will help researchers better understand the effects of this type of math remedial course, and to tailor such courses to students' needs in the future.

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