

How Engineering Technology Students Perceive Mathematics

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Abstract: Engineering Technology (ET) is often combined with that of Engineering. Although Engineering Technology is based on a more hands-on approach and Engineering a theoretical approach, the two majors share a very similar pedagogy in teaching students the same engineering and scientific principles. An observation by an ET professor found that ET students more often than not would eschew the use of mathematical computations and instead provide answers they believe to be correct, without computation or explanation. Leading researchers to delve into possible reasons as to why ET students are reluctant to utilize mathematics. This study utilized in-person interviews with 15 undergraduate participants from a Midwestern University in the United States of America from ET to ascertain how ET students perceive mathematics. The results of the study found that although ET students were stated to not hate mathematics and are open to using mathematics, there was a slight apprehension towards math due to bad math experiences and not being able to connect the conceptual nature of mathematics to the visual and real-life scenarios ET students are used to facing. The results of this study help to lay the foundation for future research studies geared towards further understanding why ET students are apprehensive towards mathematics and ultimately how to help ET students overcome this apprehension.

Keywords: *college; engineering technology; mathematics; student*

Introduction

A faculty member teaching in a university undergraduate engineering technology (ET) program from a Midwestern University located in the United States of America often observed that their students, when faced with a math problem, especially one that is unfamiliar, ET students would rely upon their intuition to answer the problem. To provide a background, the curriculum for ET students is designed to incorporate engineering, scientific and mathematical principles and methods in order to prepare ET students upon matriculating to industry positions to solve a variety of technical and engineering problems. The ET students henceforth are expected upon graduating from college to rely upon logic and fact-based information to solve these problems and to abstain from the use of intuition.

However, in the case of the ET professor's observation, the answers provided by the students would often times be presented without any supporting explanations or mathematical computations leading the professor to believe the students are choosing answers they believe to be reasonable but in actuality deviate quite a bit from the correct answer. To solidify this claim the professor presented another mathematical problem that was unlike what ET students may face in reality and therefore cannot present an answer based on learned experiences. Similarly, the answers provided departed from the correct answer by a large margin and without explanation or computations. Both mathematical problems put forth by the ET professor could have been solved using basic mathematical formulas found in the student's course packet, and yet the students refrained from the use of mathematics.

This led the researchers of this paper to ruminate whether ET students are prone to think intuitively over that of cognition and analytical approaches, especially when faced with unfamiliar situations such as that of the mathematical nature. To accomplish this, the researchers conducted an encompassing research study to first investigate the thought approach ET students rely upon to solve a variety of problems. The researchers utilized a survey and interview component. The survey questions utilized questions to gauge whether ET students are prone to relying upon their intuition or approach problems from a more logical, analytical mindset. The interview questions were designed to provide supporting evidence in the form of an insight into the personal experiences of ET students in regard to mathematics and the STEM (science, technology, engineering, and mathematics) discipline in general. The results of the study found that the students relied upon their intuition when faced with unfamiliar problems and particularly mathematical problems they were unsure of on how to solve (Lucietto et al., 2020). The data from the supporting interview component also confirmed that the ET students rely upon their intuition when faced with unfamiliar mathematical problems. However, the survey and interview data also show that ET students prefer to think analytically and logically but ultimately depend upon their intuition when the problem they face is unfamiliar. Notably, the ET students call upon their intuition when such unfamiliar problems are of the mathematical nature, leading the researchers to inquire further into the underlying reasons for these student's inhibitions towards mathematics in general. This inquisition is especially poignant due to these students pursuing a college major with a known mathematical component. Though aside from thinking intuitively versus logically, the interview questions

also revealed subtle indicators that there may be several underlying factors contributing to ET students avoiding the use of math in mathematical scenarios. Therefore, a second examination of the interview component questions was accomplished but this time from the perspective of gauging ET students experience dealing with mathematics as a whole and not just in a particular scenario. As such this research paper will focus upon the interview component as it relates to ET student's personal experiences for pursuing a STEM degree, their current reflection of their STEM experience, and reaction to certain mathematical scenarios. The results of this examination will help to further narrow down the possible reasons for why ET students refrain from mathematics and thus provide a guide for future research studies to investigate and subsequently contemplate ways to make sure ET students rely upon analytical thinking and not intuition.

Engineering Technology is an often overlooked major with a smaller annual enrollment of students when compared to that of engineering. When combining the annual enrollment of both engineering and engineering technology students, less than 2% of that total are students in engineering technology (Roy, 2018; American Society for Engineering Education, 2018). As such, studies often overlook or blend the data of engineering technology with that of engineering. Engineering and ET are similar majors and teach students the same principles and concepts but using different methods. For example, engineering teaches at a theoretical level where students are required to use computer simulations and a high degree of mathematics to contemplate and learn the material; engineering technology, on the other hand, teaches at a hands-on level where students are required

to physically perform the concepts in a laboratory setting with a small degree of mathematics to accompany the hands-on learning. Therefore, based on the observation by the ET professor on ET students possibly avoiding math due to math anxiety, led the researchers to further examine whether ET students do indeed have an aversion to math and if so is it due to anxiety or other factors that may influence this reluctance. However, a noticeable contradiction arises that if ET students do exhibit an aversion towards mathematics why then would an individual pursue a major with a known mathematical element. This conundrum leads to further questions, such as whether the subject itself may not be to blame, but rather how the subject is taught. A such several more questions may arise for addressing this topic that bear investigating, which therefore led the authors of this research paper to simplify and provide a structured foundation to grow upon for addressing this incongruity.

Literature Review

The literature review will delve into the research literature surrounding college students and math anxiety. The aim of the literature review will be to help lay a foundation of how college students react to mathematics and the possible subsequent ill effects of anxiety related to mathematics. The tenets found related to math anxiety and other factors will then be cross-examined with the findings from the interview component of this research study. The cross-examination will showcase whether the ET students do indeed show signs of math anxiety or if there may be other symptoms, outside of anxiety, that may contribute to why ET students are reluctant to perform mathematical computations. The findings will then expound upon current research and travel into a

specified direction as to align with the trajectory most helpful towards helping ET students overcome their reluctance towards using mathematics.

Anxiety related to mathematics is purported to be related to poor performance on math exams and related items and is generally inversely related to positive attitudes towards mathematics (Hembree, 1990). Numerous studies have been performed on math anxiety and its effect on an individual (Foley et al., 2017; Luttenberger et al., 2018; Young et al., 2012). Though, as to why and how math anxiety develops in an individual and its subsequent impact and lasting factor on the individual has not been universally agreed upon. This discrepancy is due largely in part to varying factors that may influence the origination and continuation of math anxiety in an individual such that definitive answers may not be able to be agreed upon. However, a few accepted reasons as to how and why math anxiety develops in an individual may be brought on primarily by: parents/family, poor math instructors, and/or an overall bad experience(s) with mathematics (Maloney & Beilock, 2012). Studies on math anxiety primarily focus on precollege students, though several studies on how college students are affected by math anxiety have also been performed (Andrews & Brown, 2015; Ramirez et. al., 2018). However, there is a lack of research on why engineering technology college students, who may exhibit traits of math anxiety/aversion, still pursue a major requiring the use of mathematics. As such, it is difficult to determine where to initially begin studying this ET population that has been rather neglected until now. Therefore, the literature review will serve as a comparison and guide for the researchers of this paper on where to begin studying an individual's experience with

mathematics by using the main contributors for what causes and impacts an individual who shrinks away from the use of mathematics. Contributors such as math anxiety, self-efficacy, and instructional methods were found to be among the most common reasons for an individual developing a dislike and subsequent aversion towards mathematics (Ramirez et al., 2018). The results of the literature review studies are compared to the ET student interview responses for this research paper study to determine any correlations among the main contributors in order to subsequently lay the foundation for future research study directions on which particular issues most impact engineering technology students aversion towards mathematics.

Effect of Math Anxiety on Precollege Students

Choice of College or Career Trajectory

A study on what college major or career trajectory, for students who have exhibited an aversion towards math may choose to pursue was performed. The study examined the developmental trajectories of math anxiety in adolescents from 7th to 12th grade using a person-centered approach based on socio-cognitive models of math anxiety (Ahmed, 2018). The models used, emphasize the importance of personal and environmental factors in the development and maintenance of math anxiety. The results of the study found diversity in developmental patterns of math anxiety during adolescence. This study and previous studies mentioned found that math anxiety levels appear stable over time which suggests for some, adolescents' math anxiety does not change. However, the findings of the study suggest that the stability of math anxiety may not apply to everyone. The study further examined the participant's math anxiety trajectories to their STEM career choice and found that participants who were ranked among consistently low

math anxiety were more likely than other students in the study to pursue and be employed in STEM as adults. This study further evinced that participants who exhibited consistently high levels of math anxiety during adolescence may contribute to why some college students shy away from STEM majors and careers (Ahmed, 2018).

College Students Attitude towards Mathematics

An individual's aversion towards mathematics as was found at times to develop during the adolescent years for an individual and steadily grow with the individual (Ahmed, 2018). Though, this observation brings forth the question on the origins of how and why an individual may react adversely towards mathematics at such a young age.

Measurement scales are one device to ascertain a student's reaction towards a situation, such as in this case mathematics. The aim of this research study paper is to gauge how ET students react while in a classroom learning and performing mathematical computations. The hypothesis by the ET professor that the ET students may have been suffering from math anxiety is a plausible theory, but it also clashes with the fact that these students willingly pursued a college major with a known math component. This leads to another plausible notion that it may not be anxiety or even mathematics in general that ET students shy away from but rather how the mathematics is taught.

The Math Anxiety Rating Scale is a scale used to rate how anxious students feel in formal and informal math settings. The formal settings could be similar to that of taking a math exam in class and the informal setting could be an everyday situation outside of the classroom where math is used, such as calculating a

grocery bill to ascertain that one was charged correctly at the store (Primi et. al., 2014). A study conducted on Italian college and high school students using the Abbreviated Math Anxiety Scale (AMAS) was used to ascertain how anxious students feel in mathematical situations. The study found that math anxiety can be reliably measured through this scale and that gender has no bearing on the results. Previous research has shown that females are more likely to suffer from math anxiety than males (Luttenberger et al., 2018). Therefore, the validity check of the AMAS for rating the anxiety of students and that the results still held true regardless of gender is helpful for future research studies regarding ET students and specifying whether these students suffer from math anxiety (Sokolowski, 2019). The Fennema-Sherman Mathematics Anxiety Scale is another scale used to study students' attitudes towards mathematics. A study on how prevalent math anxiety is among college students was conducted at The Ohio State University and involved both male and female college students who were in either a psychology course or math courses ranging in difficulty from nonadvanced to challenging. The study utilized the Fennema-Sherman Mathematics Attitudes Scale to explore this situation. The study found that avoiding math courses can begin early and that anxiety was a common thread among answers related to math exams. Also found was that higher levels of math anxiety were related to lower math scores, and higher test anxiety. Additionally, a student's age also had bearing as an increase in age may be directly related to an increase in math anxiety. Math anxiety was also found to be more likely to occur among women than men and for students with an inadequate high school background (Betz, 1978). Another study using the Fennema-Sherman Mathematics Anxiety Scale was used but this time on teacher candidates. Childhood

teacher candidates at Buffalo State College in the United States of America were used as participants to gauge whether the participants exhibited traits of math anxiety. Many childhood teacher candidates were found to exhibit fear of math, math avoidance and perform poorly on math assessments (Brzozowski, 2020). The 58 responses received from this study found that a number of childhood education teacher candidates at Buffalo State College exhibited math anxiety qualities. The results are significant as if a student's teacher exhibits an aversion towards mathematics, that aversion may be spread to students who now may exhibit anxiety towards mathematics (Brzozowski, 2020).

The effects of how symptoms associated with math anxiety affect individuals was conducted with the study examining how math anxiety affects contemporary college and university students and found that students are impacted differently by math anxiety. However, a majority have some form of math anxiety and that math anxiety can impact both mental and physical health as evidenced by findings that ranged from moderate test anxiety to extreme anxiety which included symptoms of nausea. Math anxiety may also come about by one's mindset towards grades where students may feel they might feel inadequate and fear of failing, especially during examinations. Math anxiety symptoms were also found to lead to irritation and loss of determination towards achieving success in a math class (Perry, 2004). Another study conducted at a university in Turkey on math anxiety and college students, examined the relationships between math anxiety, math attitudes and self-efficacy (Akin & Kurbanoglu, 2011). The researchers of this study utilized the Revised Mathematics Anxiety Rating Scale, the Mathematics Attitudes Scale, and the

Self-efficacy Scale (Akin & Kurbanoglu, 2011). The study found that math anxiety can harm mathematical success and that there was a negative relationship among math anxiety and thinking highly of oneself and that confidence could impact work ethic. A positive self-efficacy or belief in oneself, was found to be the center of math attitudes and math anxiety, whereas if a student has low self-efficacy in math it may relate to higher levels of math anxiety. Alternatively, if a student has positive self-efficacy that student may be more active and put in more effort to persist at a specific task despite the obstacles (Akin & Kurbanoglu, 2011).

Effect of Instructional Practices

A further progression from the revelations of math anxiety originating during adolescence due to a negative attitude towards the subject and/or poor experiences that have negatively impacted the self-efficacy of the individual to perform mathematical computations, leads to the question on whether the way mathematics is taught has a profound effect on fostering unfavorable mathematical outlooks for students..

A study focused on underlying causes of math anxiety for students, examining through the lens of teachers instructional practice provided a detailed look into the mastery and performance goals of the teachers relate to math anxiety. This study suggests that the teachers' understanding of creating mastery-oriented classrooms" may help to prevent or reduce a student's math anxiety (Furner & Gonzalez-DeHass, 2011). The study found that classroom practices may influence goals that students may adopt and that educators should endeavor to create master-oriented classrooms. Furthermore, the study stated that if math teachers

were to find a way to help students develop confidence in their ability to do math, it may impact the students' lives. A further study performed on 770 college engineering students at a University in Malaysia, explored the factors related to math anxiety on these students. The researchers employed a 30-minute survey questionnaire with responses utilizing a scale to gain a better understanding of students' experiences and opinions with math. The researchers found that math anxiety manifested into five dimensions for these students and are as follows: feel math is a difficult subject, always fail in math, always having to write in math class, anxious if they do not understand, and loss of interest in math. Additionally, according to student beliefs, concentration and memorization is needed for math. Also found was that females experience math anxiety more than their male counterparts (Vitasari et al., 2010).

Student Inhibitions

A student's self-efficacy may be another contributing factor to why certain students excel and fail in certain areas. The case of mathematics, students may excel in other subjects such as social studies, physics, and chemistry but fail in mathematics due to a poor experience or not being able to comprehend the subject as quickly as they may have for other subjects such as chemistry. Leading the student to constantly believe they are not good at this particular subject and as a result neglect to put forth any extra effort towards understanding and mastering a subject they believe is a hopeless cause. Standardized testing is one such situation that may contribute to a student developing behavioral inhibition. A research study conducted on 184 undergraduate students from a large public university located in the Southwestern United States of America, were examined on how a student's

personality and temperament affect their performance in standardized math tests and course grades. The study found that individuals with high fear and avoidance sensitivity were prone to experience distress in stressful or high-stake situations of which affects their performance (Liew et al., 2014). Indicating, that students may not be exhibiting anxiety necessarily towards math but rather a general form of behavioral anxiety related to high-stake situations such as tests and the fear of failing (Liew et al., 2014).

Effects of math anxiety on student's inhibitions and working memory was researched. The study sought to examine how the concept of expressive writing may be used to alleviate the ill effects of math anxiety of students before taking a math exam. Expressive writing is a clinical technique that encourages one to freely notate their thoughts and feelings regarding a stressful situation that the individual is facing. The benefits of employing expressive writing from previous studies has shown to provide physical and psychological benefits and to also increase the availability of working memory resources (Klein & Boals, 2001). A research study sought to examine the effects of employing expressive writing before taking a math test. The study comprised of 42 engineering undergraduate students from an Indian institution. The participants were divided into control and experimental groups, where the control group was asked to sit quietly, and the experimental group was asked to write about their feelings prior to taking a math test. The results found that the experimental group performed better on the math test than the control group, indicating that the experimental group had better access to working memory and were able to use their mathematical and cognitive skills better than the control group (Jaltare & Moghe, 2020).

Literature Review Summary

The research studies mentioned in this literature review show the different facets of how an individual may react towards mathematics. Specifically, it shows that anxiety may not be the ultimate culprit for why an individual may react hesitatingly towards the use of mathematics as shown in the example for ET students. An individual's reluctance to use mathematics may stem from several causes which may include but are not limited to: math anxiety, poor math instruction, test anxiety, and low self-efficacy. These potential causes will be cross-examined with the results from the interview component of this research study to survey whether the ET students exhibit any of these traits. Once the results are found further examination may be administered in the affected area(s) to further inspect the reasons for how and why these ill traits have rooted within ET students. Students graduating from an engineering program such as these ET students will often enter industry and assume the role of engineer. As such, math is a steadfast companion to engineering projects and requires one to perform computations correctly the first time, especially if the product is used in contact with humans. Therefore, it is crucial to determine the underlying reasons for why ET are reserved or inconsistent when faced with performing mathematical computations.

Research Study Overview

Based upon the literature from previous studies on the impact of math anxiety and associated factors on college students and precollege students helped to formulate a set of interview questions to glean insight into how ET students are impacted by poor math experiences, if any. As stated, ET is a neglected field of study regarding research performed and as such it is unclear what areas to initially focus upon specifically

for this particular population. Therefore, this research study is intended to combine the factors related to math anxiety found in the literature review to formulate a foundation from which to grow upon based on the findings of this study and then subsequent studies.

Research Questions

The research questions will aim to inspect whether ET students may suffer from an aversion towards mathematics and if so, does self-efficacy have any bearing on their ability to solve math problems or in any other area of their major?

1. Do ET students exhibit any symptoms of math aversion?
2. If a participant had a bad experience with mathematics, does that experience impact their confidence when performing mathematical computations?
3. Does a participant's confidence in their academic abilities affect their academic performance, especially during a mathematical test/exam?
4. Do the instructional practices used by precollege and college math teachers have any effect on a student's perception towards mathematics?

Methodology

The interview aspect analyzed for this paper was part of a larger encompassing study that involved a survey element as well. The encompassing study was performed at a Midwestern University in the United States of America and was focused on gaining an insight into how ET students think and approach problems and if the students may have been exhibiting

any symptoms of math anxiety. Specifically, whether ET students were prone to thinking intuitively rather than cognitive/analytically. Though, for this research paper only the results from the interview element will be analyzed to ascertain whether traits of math anxiety are present or if other underlying factors contribute to ET student's reluctance to use mathematics.

Participants

The participants recruited for this research study were college undergraduate ET majors. The age range of the participants were between 18-22 years of age. Further, the participants year of study ranged from Freshman to Super Senior (+4 years). The interviews were catered towards primarily female and/or minority students in engineering technology though all genders and race groups could participate. The total 20 participants recruited for this study comprised of 16 female and four male undergraduate students. Furthermore, of the participants 15 were from ET, four from Engineering, and one from Liberal Arts. The variability in the majors of the participants included participants outside of ET due to inspecting whether the responses from ET students were unique to just ET or may be shared among other college majors. Though, the focus of this research paper is just on ET majors and therefore for the purposes of this research paper only the results of the 15 ET participants will be analyzed.

A primary focus was upon female and minority students due to these particular populations of students being more likely to suffer from aversion and/or anxiety towards mathematics. However, due to the limited variability among gender and race that was procured for this study the results will be analyzed in aggregate. Though, a brief inspection was performed

to ascertain the female ET student participants perception on being in a male dominated major.

Procedure

Participants were recruited using two main methods. The first method was done via the survey questionnaire where upon completion participants were afforded the opportunity to partake in the interview component. The second method was done by sending out a recruitment email through the ET college faculty. A superficial third method was used in the form of referrals through participants to advertise this study to their friends and fellow students in ET.

This study procured data via an in-person interview setting using a total of 20 participants. The in-person interview took place in a small conference room on the university campus between the researchers of this paper and the participant. The interview was voice recorded whereupon the voice recordings were then converted to a written transcript format to be used for qualitative analysis. Anonymity was used throughout the interview with no identifying or personal information discussed or asked to the participants at any point before, during, or after the interview. The only information related to the participant to be recorded was their gender, major of study, year of study and whether they were of a minority race. Additionally, the only other identifying information regarding the participants was official documentation indicating their consent to participate in the study by acknowledging and providing their written signature for the participant consent form and acknowledging they received their \$10 Starbucks gift card upon completion of the interview.

Interview Questions

The interview was designed to last no more than 30 minutes. The interview questions composed of 21 questions, as shown in Appendix A. The questions were grouped under seven major section headings and are as follows: Home life, Academics, Perception, Scenario's 1 and 2, Fill in the Blank, Peer Pressure, and Open Discussion. Each of these sections are meant to delve into a participant's background and personal experience with academics as it relates to mathematics, STEM, and self-efficacy.

The Home Life and Academic questions may lay the foundation for whether students were pressured to attend college and/or choose a certain major. Additionally, whether the students had concerns in their ability to handle college and/or a STEM major. The scenario questions may allow for insight in how the participants initially approach problems whether they are math or otherwise. The Peer Pressure questions will allow insights into whether confidence in themselves has bearing on how likely the participant is to work hard to succeed in a course; specifically, if the participant is not confident or are confident in their ability to muddle through a challenging STEM course or otherwise. The group work questions embedded within the Peer Pressure section may lend support to the peer pressure situations in terms of confidence, inclusion, feeling part of a group, etc. Finally, an Open Discussion question was posed to the participant's if they would like to add to statements from the interview on their or any another's person's observations as it related to the questions posed. Due to the initial foray into examining ET students and their reaction towards mathematics, the interview questions were generalized as ET is a field of study with little literature and therefore it was unclear what exactly to focus upon and

what might be found with this, until now, neglected field of study. As such, based on the insights from this research study, future studies may now be specified in a particular direction to further inquire as to the root causes of why ET students abstain from the use of mathematics and if any changes in faculty instruction may need to be considered.

Data Analyses

The interview data was inspected via qualitative analysis using a combination of qualitative software NVivo (QSR International, n.d.) and visual perusal for recurring words and themes for each of the question sections. However, due to the unique responses from each of the ET participants, a visual representation of frequently used words could not be compiled. Instead the results will discuss the themes present from the participant's responses. The responses for final section of Open Discussion will not be evaluated here, as the responses for this question did not include anything new that the participant had not already stated in response to an earlier question.

Results

The full list of questions asked to participants during the interview may be found in Appendix A. The results of the responses discussed here summarizes each response of the seven main section headings as it relates to addressing the research questions of this research paper.

Interview Questions Section 1: Home Life

Students' responses to Home Life questions are intended to delve into family support of higher education. Regarding whether participants were encouraged to attend higher education and any concerns they may have had pertaining to higher

education, it was found that all 15 participants were encouraged to pursue higher education, with all participants stating it was mandatory and expected by their family. Four of the 15 participants knew from elementary and middle school that they would attend higher education with three participants stating that it was expected of them and that they were not even aware there were other options other than higher education. Additionally, three participants mentioned a parent/family member who was already in a STEM field which may have influenced the participant to pursue a STEM discipline.

Furthermore, when asked if participants had any concerns entering higher education the responses centered mainly around finances to pay for college and acclimating to a new environment. One participant did state that their concern for higher education stemmed from having to utilize mathematics as part of their ET major. This participant had also stated that they had consistently struggled with understanding and applying mathematics starting from their adolescent years.

Interview Questions Section 2: Academics

The Academic questions related to participant perception of STEM courses and their experience thus far with STEM courses. Additionally, questions regarding whether participants have a hate or dislike for math as well as describing a bad moment with math will be examined as well, in addition to other supplemental questions. When asked how participants would describe STEM courses, a consensus was found that STEM courses are generally difficult. Three participants further added the descriptors of: *off-putting, challenging, and time consuming*. Although all agreed they are difficult, 8 participants also

described them as applicable to the real world regarding how things work and how to solve problems outside the classroom. Similarly, one ET student mentioned that although STEM classes are hard, they are enjoyable as they make everyday events around them make sense. This viewpoint was shared among ET students, where the consensus was that STEM courses are difficult but are applicable to the real world and helps to understand how things work.

Another observation of the interview data found was that when participants were asked to name a favorite STEM class the ET students cited courses with a lab or similar hands-on aspect as their favorite.

The next set of observations comprised of whether the participants considered themselves to be overachievers and if so whether it has impacted the way they view math courses. Eight participants indicated they were overachievers and two indicating they were perfectionists and that at times being an overachiever did impact the way they view math courses. Four participants indicated that whether they enjoyed a course or not impacted how much effort they were willing to put forth for that class, with a correlation of joy and more effort and less joy less effort.

Subsequent questions related to whether the participants had a hate for math and if so when it began; followed by a question to describe a bad moment with math. The responses for whether participants had a hate for math yielded 10 out of 15 participants stating they have a dislike for math but did not hate the subject. Though one participant stated they try to avoid the use of math whenever possible. The 10 participants stated that their dislike originated

due to receiving low math test scores, having difficulty learning the new material, but six participants cited the course structure and math instructors as to the origin of why they dislike math. Five students cited college Calculus courses as when their dislike for math began due largely in part on doing poorly on the exam and citing poor instruction from the instructors. The students described the college Calculus instructors as not being able to communicate information properly or clearly. Furthermore, students who developed a dislike for math before college cited that although the content was difficult at times, it was not the reason for the dislike rather the instructors who would not convey the material properly, not be open for questions, and would embarrass the student for a low score. Furthermore, several participants (regardless of math dislike) cited low college math exam scores as a turning point in their confidence to succeed. Sometimes, students claimed they would study extensively and work on homework for hours only to receive a low score for their efforts. However, when referencing a previous interview question on participants favorite STEM course, the courses cited most often for ET students were those with a hands-on application aspect. The ET participants regularly mentioned that being able to connect the learning material between courses and see how it all relates and builds was preferable as it provided a purpose to learning the material. A student when asked when their hate for math began stated:

“Calculus 2. Wasn’t hate for math just the way it was taught. Felt they could’ve done a better job. The teachers didn’t seem to be interested and just seemed like you were being forced to learn something that didn’t

really connect to your field at all. They like classes they can connect to something they are going to do. If class shows how it relates to another class or job field then those are interesting. Classes that are just a bunch of math and you learn it doesn't feel like its applicable to the rest of what your doing. Also haven't seen some math concepts since they took them in Calculus 2 and feel like the skills learned in that class are not going to affect what they will do in the future."

Interview Questions Sections 4 and 5: Scenario and Fill in the Blank Questions

A summary of the most frequent words used to describe STEM related classes, found that all the participants described STEM courses as difficult with three participants specifically stating the classes to be *challenging* and *hard*. Though, the ET students believe that the STEM classes generally are hands-on and offers the most practical benefit and teach learning skills most applicable for the real world.

The results on how participants would feel if they had studied for two weeks for a math class were divided between feeling good and nervous. The ET students stated they would feel good but still a little nervous that they might second guess themselves or have studied the wrong material. One interview participant was summarized as saying,

"Studying for math is always kind of tricky because you can do all the problems but on the exam it might be something completely different."

The overall emotional average stated they would feel good and not worried as they feel they know the

material well. However, three respondents stated they would be nervous due to the fear of having not studied the content that will actually be on the exam. Due to the limited time for faculty to give examinations, it is not possible to test all the material learned and thus only certain content will be tested. This led to three respondents stating that they would be nervous that they may not have studied the content that will actually be tested on the exam.

The responses for how a participant would react upon seeing an unfamiliar math problem was universal. All respondents claimed they would initially panic but would then try to calm down and think of past material or related material that might help them reason through the problem. Often, the students would choose to skip the problem until all other questions have been answered and then try to reason through the unfamiliar problem and how the answer they chose is correct.

Interview Question Sections 3 and 6: Perception and Peer Pressure

The Peer Pressure questions were designed to examine whether a participant's gender and/or race has any influence on a student's confidence or mentality in certain situations, as this could impact an individual's self-efficacy for performing certain difficult academic tasks such as that of mathematical computations. Responses to the question regarding how a female may feel if they are the only female in a course had a mix of all female responses ranging from not being bothered to a few feelings of being uncomfortable. The responses, furthermore, indicated that females, regardless of major, felt a bit alienated to be one of only a few females in a class and at times felt discouraged from asking questions. Though, a summary statement by one female participant stated

that sometimes being the only female in a class of primarily males causes one to strive to prove themselves and feel proud at times to be one of only a few females. All the 11 female ET participants indicated that being the only female or one of only a few females in a class was not uncommon and they felt uncomfortable at first but overtime it did not bother them as much. For group scenarios the responses were a mix of female participants stating they would take charge initially of group discussion to other participants stating they would only speak up when no one else does with others going along if someone else speaks up first. Overall, regardless of gender or race, participants who felt alienated in a group may feel awkward and uncomfortable at first but would try to get over that because obtaining good grades and GPA overrule any feelings of awkwardness in a group situation.

Discussion

The findings from the interview data provide a preliminary look into how engineering technology students perceive mathematics. The initial belief, referencing the introductory observation by the ET professor, was that math anxiety may have been the factor affecting ET students and their ability and willingness to engage in mathematics. However, from this initial foray examining the interview responses on understanding how ET students regard mathematics it was found that ET students do not show obvious signs of suffering from math anxiety. A comparison to the literature review studies from the section on the effect of math anxiety on precollege students choice of college and career trajectory found individuals who consistently ranked low on math anxiety were more likely to pursue a STEM major than those with high

math anxiety (Ahmed, 2018). Additionally, the summary of frequently used words on ET students describing STEM courses as “hard” and “challenging” but applicable to the real world observation, does not align with the patterns of an individual suffering from math anxiety. A definite consensus however cannot be determined at this time since the participants were not asked if they do suffer from math anxiety. Though, one participant in response to the question of whether they had any concerns about higher education, the participant openly stated that having to use mathematics as part of their major was a major concern as they never performed well. This particular participant had stated that they had always struggled understanding mathematics starting from adolescence and yet the participant willingly chose a college major where mathematics was a requirement. This observation is in contradiction to the research study that found students who consistently ranked with high levels of math anxiety were less likely to pursue a STEM major or STEM career trajectory (Ahmed, 2018). Therefore, although it was not blatantly stated by the participant, it would prove appropriate to further investigate for future studies to ask participants whether they do indeed believe themselves to suffer from math anxiety. Especially when the participant states they have struggled with understanding mathematics from a young age (elementary or middle school age). Furthermore, the research study found individuals who develop adverse feelings for mathematics at a young age, those adverse feelings appear to remain stable over time as the individual matures (Ahmed, 2018). As such, the participant who stated that they have struggled with mathematics since adolescence and tries to avoid even while pursuing an ET degree bears further investigation.

As stated earlier, ET graduates will often enter industry as engineers and must perform mathematical calculations on the daily. Therefore, even though an individual may enjoy other facets of engineering enough to pursue the major despite the use of mathematics, it would prove dangerous upon graduation when that individual is responsible for designing products used by living beings, such as bridges.

The results of the Home Life questions indicate that participants already knew early on they would pursue a higher education degree and that even if some participants had concerns, those concerns did not greatly impact their decision to still pursue a higher education. Additionally, participants who have a family member working in a STEM field may have influenced the participants choice of college major early on in life. Indicating that even if the participant may have developed math anxiety before college, the familial influence toward a STEM major overpowered any concerns about pursuing a major with a math requirement. This observation is aligned with the claim that if an individual developed any adverse effect towards math, such as math anxiety, at a young age that effect would remain stable over time and may even affect the individuals decision to abstain from a future college major or career in mathematics (Ahmed, 2018). Therefore, that participants indicated early on to pursue a college major and especially for those who had familial ties to a STEM category and thereby also pursuing a STEM major, leads to a possible future research inquiry on whether an individual's familial influences for a college major with a math component may prevail over any ill feelings the individual will have regarding math. Furthermore, the inquiry could also indicate if this early confidence in pursuing a

major with a known math component may inadvertently boost an individual's self-confidence to not be waylaid by any bad precollege math experiences and thereby persevere to obtaining the math related college major (Akin & Kurbanoglu, 2011; Liew et al., 2014).

Based on the results of how the participants described STEM courses may indicate that participants genuinely enjoy or at least understand the value of a major that teaches one knowledge that can be applied to real-life scenarios. As such, when compared to the results of the Home Life questions, family may have pressured participants to pursue a higher education degree and that of a STEM major, but the participants may also intrinsically have chosen a STEM major.

From the Literature Review section it was stated that there could be other factors outside of math anxiety that may explain why an individual may shy away from the use of mathematics which are but are not limited to: poor math instruction, test anxiety, and low self-efficacy.

The instructional methods used by precollege and college math teachers was a recurring theme mentioned by the participants when relaying a bad experience with math. All of the 15 participants did not mention having a hate for math, but 10 participants did mention that they have a dislike or at least apprehension towards mathematics. The 10 participants stated the dislike was mainly due to low test scores and difficulty learning the new material. Though, 6 of the 10 participants who stated to dislike math mentioned that the course structure and poor math instruction as to the cause of their dislike towards mathematics. The methods utilized by instructors

when teaching students math has been found to affect whether students may or may not develop apprehension towards mathematics (Furner & Gonzalez-DeHass, 2011). Therefore, referencing the initial observation by the ET professor as to why students shy away from the use of mathematics may not necessarily be because the ET students have anxiety but because they were not taught how and when to properly apply the mathematical formulas to a problem. These deleterious pedagogies may be further examined by asking participants specific questions on what exactly was wrong with the methods utilized by the precollege and, especially the college math teachers, that would instill such an unfavorable core memory related to mathematics. Furthermore, future interviews may also be performed with ET professors on their instructional methods and whether they themselves suffer from any anxiety related to math that may affect their instructional methods and thereby their students. A comparison of instructional methods utilized in the classroom as evinced by students and professors may be helpful in determining problem areas and how to then go about improving the pedagogies to support favorable learning experiences for both students and faculty (Šimić Šašić, 2018; Brzozowski, 2020).

Test anxiety was another factor as to why ET students may provide math answers based on intuition rather than analytical computations. The three participants who stated they would feel nervous before a math exam despite having prepared for two weeks may attest to this claim, citing fear that they may have studied the wrong material. Furthermore, when asked how a participant would react upon viewing an unfamiliar math problem all 15 participants stated they would be nervous initially but would eventually calm

down and try to reason through the problem. Though, participants did state that on a math exam if they could not solve the problem initially, they would skip the problem and come back to it once having answered all the other problems. If they still could not answer the problem, they would provide an answer they felt would be correct. This harkens back to the claim that ET students may rely upon their intuition when placed in unfamiliar situations (Lucietto et al., 2020).

Finally, confidence one has in their academic ability was briefly examined regarding how the 11 female ET participants feel when placed in a class or group where they are the only female. This was inspected due to females being more likely than males to suffer from low self-confidence and a higher likelihood to suffer from math anxiety (Betz, 1978; Akin & Kurbanoglu, 2011; Sokolowski, 2019). All female participants stated that initially they would feel uncomfortable, but overtime would become more comfortable. Further, all participants (regardless of gender or race) when asked responded the same that despite being in the minority they would become more comfortable overtime within the dynamics of the class/group. Additionally, the need to do well in the course to improve their GPA would also eclipse any inferiority complex they may feel in their academic abilities compared to their peers. Therefore, the claim that females are more likely to develop math anxiety and suffer from low self-confidence may not necessarily hold true (Betz, 1978; Vitasari et al., 2010). Based on this initial observation, the need to succeed academically overcomes any feelings of inadequacy that females may feel in regard to being a minority among males. Though, future research studies would benefit from investigating whether a trend may have formed where females are less likely overtime to

suffer from math anxiety and/or any feelings of low self-confidence when placed in a situation where they are the minority.

Conclusion

The overall results of this research study found that although ET students may exhibit a mild aversion towards mathematics, it is not clear whether that aversion is due to the subject matter itself or poor instructional methods used to convey the information. Although, a bad experience with mathematics may have caused some lack of confidence when performing mathematical computations, especially those on a math test/exam it has not deterred the students from pursuing mathematics or a major requiring the use of mathematics. Rather, the lack of confidence is due more to test anxiety than math anxiety as attributed to a fear of studying the wrong material. Though, general confidence in oneself does not appear to impact one's academic ability. This observation was briefly investigated by asking how female and minority race ET students felt being the only one of their gender or race in a classroom setting. Based on this initial examination students who are not of the demographic majority stated they would feel uncomfortable at first but ultimately the pressure to obtain a good grade and improve their GPA ultimately eclipsed any low self-efficacy they may have had in their academic abilities. Though, the answer as to whether instructional practices used by precollege and college math teachers having an effect on student's perception was more conclusive with participants at times directly referencing poor math instructors as the cause for the participant to develop an aversion towards mathematics. The correlation of the interview findings to results of the research studies from the literature review was helpful in determining how ET students

compare to students who expressly exhibit math anxiety and overall aversion towards the subject of mathematics. The correlation helped to lay a foundation for future research study directions on what and how to go about investigating these ET students in a more specified direction. Namely, further examination on the instructional practices used not only by math instructors but ET instructors would need to be investigated as several ET participants cited poor instruction as the cause of math aversion. The origin of this research study was based upon the observation by the professor of the Dynamics course for ET students who observed students abstaining from the use of mathematics possibly due to math anxiety. Though, based on the interview findings, it was found ET students do not show blatant symptoms of suffering from math anxiety but rather any grievances related to math were attributed mainly to the poor instructional methods used by past and present instructors. Overall, future research studies would need to be undertaken to confirm the initial findings of this small-scale study with a particular emphasis on assessing the instructional methods used to teach ET students.

Future Work

Due to the small-scale nature of this research study there are several areas of improvement that may be undertaken for future research studies. Namely, increasing the number of participants to a much larger quantity in order to obtain a more conclusive finding to represent the overall ET population. As the interview findings of this paper were compared to the findings from several other research studies on the affect and presence of math anxiety and associated poor mathematical contributors, it would be promising to now compare ET students to other specific college

majors. Notably, it was mentioned that engineering and engineering technology students are similar in the content they are taught with the instructional framework being the difference. Therefore, future research studies could compare mathematical experiences between that of engineering technology and engineering students to ascertain similarities and differences in the experiences. In addition, the small insight gleaned for this research study on an individual's confidence appeared to have had an effect on the approach one used when faced with an unfamiliar math problem and therefore further research on specifically examining an individual's self-efficacy and overall inhibitions in certain situations would prove promising for ascertaining the effect on the individual's academic ability and overall thought process.

Further investigation into the reasons as to why ET students are reluctant at times to use mathematics would need to be accomplished. Notably, further work would need to still include math anxiety and explicitly ask students if they suffer from the effects of math anxiety. This may initially be accomplished using the Mathematics Anxiety Rating Scale, the Mathematics Attitudes Scale, and the Fennema-Sherman (Akin & Kurbanoglu, 2011; Primi et al., 2014).

The use of the Math Anxiety Scale and the Fennema-Sherman measurement scales would need to be used to formally ascertain how ET students react and perceive mathematics as a whole and the way mathematics is taught in the classroom (Primi et al., 2014; Sokolowski, 2019). Future research studies may also recruit ET professors to participate to ascertain whether they suffer from math anxiety or aversion towards math that they may be subconsciously

projecting onto their students. Furthermore, how an ET professor presents material and how they require the use of mathematics in their course needs to be examined as the professors may not be presenting the material in a manner for students to be able to understand and then apply to a problem/scenario.

Deliberating possible methods to curb aversion to math should also be considered for future implementation. At this point it may be too soon to allocate specific methods but methods such as expressive writing should be considered and possibly researched concurrently with determining how ET students perceive mathematics and deliberate other possible reasons for why ET students are reluctant to use mathematics (Jaltare & Moghe, 2020). In the case of the one ET participant who has stated to be apprehensive towards mathematics since adolescence, may benefit from the clinical method of expressive writing. Likewise, students as a whole who do not dislike or have any ill feelings regarding mathematics may still benefit from expressive writing before an exam as it could placate any test anxiety an individual would feel regarding high-stake situations such as final exams. Additionally, an initial option may be to employ self-regulation strategies to improve students' attitudes towards math (Tee et al., 2018). Student's commented from the interviews that learning mathematics is different than the learning styles used for other courses, especially Liberal Arts courses. As such, these different learning styles required to learn math may add undue pressure on the students to not only learn unfamiliar concepts but also to learn via foreign pedagogies. Therefore, these strategies may help to introduce a structure for the students to learn and motivate themselves which may lead to a confidence boost to do well and strive to learn the

concepts. Thereby, fostering an environment for students to develop a positive attitude towards mathematics which may then lead to a decrease in test anxiety and bad math experiences that have caused these students to avoid interactions with mathematics.

Previous research studies have shown that an individual's confidence in their ability to perform a task has bearing on how likely that individual will succeed at said task (Liew et al., 2014). For this research study in response to the question on how a participant would feel if they had two weeks to prepare

for a math exam, all but three participants stated they would still feel nervous. Therefore, that nervousness may impact their confidence in their ability to reason through the math questions and cause them to provide wrong answers even if the individual does indeed know how to perform the correct computations. As such, methods for helping students boost their confidence may be another future research study area to help students overcome these ill effects during their college years so they may then go on to become reliable and efficient engineers.

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Appendix A: List of Interview Questions

Home Life

- Question 1: Were you encouraged to attend college?
- Question 2: When did you know you wanted to be involved with higher education?
- Question 3: Did you have any concerns about higher education?

Academics

- Question 4: What is your major? What year are you?
- Question 5: How would you describe STEM related classes?
- Question 6: Do you have a favorite STEM class?
- Question 7: Did your high school offer STEM courses? If so, which courses?
- Question 8: Do you consider yourself an over achieving? If so, do you think that has impacted the way you view math courses?
- Question 9: If you have a hate for math, when did it begin?
- Question 10: Describe a bad moment with math.

Perception

- Question 11: How do you think others view you within STEM?
- Question 12: Has that viewpoint impacted any of your ways (methods, thought processes)?

Scenario 1

- Question 13: Today is exam day for your math class. You have prepared for this test for 2 weeks how do you feel?

Scenario 2

- Question 14: Assume you have never seen this problem

Find the value of $\cos 75^\circ$

How do you react? What is your thought process when seeing an unfamiliar math problem?

Fill in the Blank

Question 15: Math is ____

Question 16: When I was younger (K-12) math was ____ and now math is _____.

Peer Pressure

Scenario 3

Question 17: If you felt alienated in a group, would you still attempt/put effort into the project?

Scenario 4

Question 18: You are the only female (person of your race) in a lecture for a math class. How does this make you feel?

Question 19: Has this happened to you in any STEM class?

Scenario 5

Question 20: The professor of a math class has assigned 5 people per group for a project. You are the only female (person of your race). Do you initiate the discussions?

Open Discussion

Question 21: Open Discussion/Additional Information about you or anyone else?

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