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Math Anxiety: Engineering Technology Students Problem Solving Through Rational or Experiential Context

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Therese Azevedo is a third year student at Sonoma State University pursuing a Bachelor of Science in Statistics. Over the summer she had the opportunity to work with Dr. Anne Lucietto and Meher Taleyarkhan (Graduate Student) on a project related to math anxiety focused on female and minority students. Therese has been able to continue this project with her research advisor, Dr. Natalie Hobson, at her home institution.

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Abstract

Math anxiety is a pernicious problem. The issue manifests in a variety of ways, some avoid math completely, while others enact coping skills to avoid the use of math. This study surveys students who are pursuing Engineering Technology degrees and delves into the tendencies of the students and how they utilize certain types of problem-solving techniques. The survey utilized the instrument Cognitive-Experiential Self Theory (CEST) [1]. The survey will help to learn the extent to which the students rely on the rational and experiential context of their lives to answer technical questions. The study is intended to enlighten educators and others to the degree intuition is used by students as a means of problem solving. The conclusions drawn will help to develop techniques to encourage students to have a more positive view of mathematics and to use mathematics for solving technical problems. The overall results will help to support future work on math anxiety and to develop methods to curb students' negative reactions to scenarios contributing to math anxieties.

Keywords*: Math Anxiety, Use of Cognition, Faith in Intuition*

Introduction

Students, graduates, and the overall population are subject to the effects of math anxiety. While these observations are largely anecdotal [2], the effects of having math anxiety can be devastating, as mathematics is an important part of life [3]. Math anxiety can cause individuals to avoid math or situations that require analytical and rational thought [4]. Several studies have been carried out with elementary and grade school students to learn more about human reaction to mathematics [5], yet fewer studies have been done on college students or later. Furthermore, the majority of these research studies on college students focus on first-year students enrolled in a mathematics course [3]. The current study of this paper is focused on a less studied population of engineering technology students, and their tendency to engage in rational-analytical thought processes.

Literature Review

In the 1970's researchers indicated that math anxiety was on the wane [6]. Research shows this is not the case and may instead be increasing. The two areas that were of primary focus in the 1987 study were female and underrepresented minorities. The researchers found that female and minority students had higher levels of math anxiety than their peers, this was true for school students but also individuals in the general population. This brings to light the issue that different groups of students may be more likely than others to suffer from math anxiety.

Female and/or Underrepresented Minority (URM) Students. As we move forward in time we find that female teachers who exhibit math anxiety can significantly impact their own students' levels of math anxiety [7] and therefore contribute to students' higher levels of math anxiety. Teachers, a majority of which are female report that they first experienced math anxiety while they themselves were young, which then developed and solidified the anxiety as adults [8]. Teachers, a majority of which are female, in a Head Start program for pre-school students reported higher levels of math anxiety and low levels of math confidence. Those teachers who were more confident in their ability in math, reported on liking math and incorporating more math in their lessons than teachers who were not confidant in their math abilities [9].

The general student population was found to have a negative correlation between general test scores and test anxiety and math anxiety [10], that is, students with higher levels of math anxetiy are reported to have lower exam scores. Therefore, as students become less confident in their test taking abilities, they exhibit issues with scoring, and this generally relates to the amount of math anxiety they exhibit. Some suggest that students exhibiting math anxiety will cope by avoiding tasks requiring a solution requiring the use of math [11]. By doing this, students learn less math and develop less understanding of the math concepts. Maloney and Beilock [11] assert that these individuals' worries about math also compromise their cognitive resources, which limits their ability to stay on task. This ultimately causes their mathematical performance to suffer, creating an unbreakable cycle.

Ways of Dealing with Math Anxiety – Coping Skills. Students generally are found to be math anxious when their math scores dropped [11]. As noted earlier, when the scores drop, one develops a sense of inadequacy and overall feeling of failure. These individuals develop a way to avoid such tasks by doing something else; one may refer to these as *coping skills*. These coping skills often ultimately result in avoidance of the subject altogether. While searching for relevant material on coping skills related to math anxiety, little was found. Many researchers utilized scales such as the math anxiety scale to determine how math anxiety manifests in individuals, but not how those individuals cope with the math anxiety issue. Most cite avoidance as the most utilized means of dealing with math anxiety. These studies on avoidance, primarily focused on pre-service teachers [12] and middle school students [13]. Predictors were used during these studies, such as the math anxiety scale, of which the results helped to see if any of the coping skills observed were a predictor of math avoidance [4]. While these coping skills are generally observed behaviors, the choice of student major may also be an indicator reflecting the use of avoidance of math.

Technical Degrees Pursued Despite Math Anxiety. Students experiencing math anxiety are often known to choose non-STEM majors or avoid math courses as much as possible [4]. However, the student population observed in this study consists of primarily engineering technology majors at a large university. Many of these students are a direct matriculation following high school, some transferred in from engineering and others from non-related programs. When examining statistics on student performance, engineering technology students

have lower overall math scores on standardized tests than their peers in engineering, on average nearly 10% lower [4]. Further consideration of ABET accreditation requirements shows the most significant difference between engineering technology and engineering are the math requirements with two semesters of math versus four semesters of math, both beginning with Calculus I, respectively [14, 15]. Considering one of the coping mechanisms as math avoidance, many of the students may be choosing the major with less math requirements to deal with math anxiety. The researchers for this paper did not find any research on whether students chose a major based on math anxiety, and as such intend to probe this issue further in another study.

Abbreviated Math Anxiety Scale

The Abbreviated Math Anxiety Scale is usually utilized to develop an understanding of how math anxiety manifests itself in students and the general population – most often in children [16]. This scale while valuable in several settings does not support the main questions being asked in this study. Further investigation into other scales provided support for the use of the Cognitive-Experiential Self Theory Scale to evaluate the processes utilized by the study population to problem solve.

Use of Cognition. Anecdotal observations made by faculty in the classroom found that students in engineering technology often choose to pick what they believe to be a reasonable response to a question without employing the use of a mathematical formula or apparent analytical thoughts. These responses are often not calculated, nor explained. One engineering technology professor teaching a Dynamics course asked the students to find an elliptical orbit around the Earth that has a period of 24 hours. The answers to this problem come from direct and simple applications of equations explicitly presented in the note pack.

Suspecting that the students were using an intuitive approach by guessing at the answer and not utilizing a cognitive approach, a problem was designed to give answers that lay outside these students' intuition, forcing the students to calculate the answers to the problem, and not allowing them to guess based on their experience. The professor once again found that the students used inferential answers and did not substantiate how or why they answered the question the way they did affirming the findings from the orbital problem. Thus, leading the researchers to inquire about individuals' reliance on using intuitive approaches to solving problems over that of cognition.

Engineering technology students are used to solving problems using hands-on methods based on learned experiences and common sense. In contrast to engineering students founded in theoretical knowledge, engineering technology students utilize scientific theoretical principles and apply the knowledge to real world problems. As such, solving many realistic problems such as repairs to a car engine may be based on learned experiences with no need to undergo any set cognitive methodical approaches to ascertain the problem. Therefore, it is relatively easy for engineering technology students to eschew cognitive methodology in favor of intuitive analytical

processes. Although engineering technology students may prefer cognitive approaches, when in doubt or under pressure, they may revert to the use of intuition. However, decisions based solely on intuition is dangerous for engineering and engineering technology fields where reliability and consistency are tantamount to safety. A review of literature was conducted and found very little research studies on engineering technology students refraining from cognitive approaches in favor of intuitive approaches.

Research Questions

This current study surveys students who are pursuing technical degrees and delves into the tendencies of the students to use a cognitive thought over intuition and how they utilize certain types of problem-solving techniques.

What are engineering technology students' tendencies to want to engage in situations requiring rational or experiential processing skills?

Methods

A survey was developed using two different validated instruments and the addition of general demographic questions to frame the context in which an individual may respond to a set of questions while preserving individual identity. The instrument examined in this paper is the Cognitive-Experiential Self Theory [1].

Cognitive-Experiential Self Theory (CEST). The CEST [1] evaluation of thinking styles is the result of work done by psychologists in a wide variety of areas. These psychologists determined there are two different modes that an individual will use to process information. These two modes are *intuitive-experiential* and *analytical-rational* [17]. The scale chosen determines the preferred type of thinking utilized by individuals in a variety of settings on whether the individual is prone to relying upon intuition based on learned experiences or employs a rational, logical approach [1].

Use of Rational and Experiential Contexts of Life. Utilizing the CEST instrument [1] will allow the researchers of this paper to determine if engineering technology students, when using cognition in academia and daily life if their thought process is more *intuitive-experiential* or *analytical-rational*. The results of this research will provide insight into how these students think and as a result proper modification to curriculum design for engineering technology students may be implemented in order to train these students to employ analytical approaches rather than depending upon intuitive methods.

The researchers will examine the survey data first looking at the aggregate responses and then focus exclusively on engineering technology majors and their responses to questions in each instrument to learn more about these students and the potential reason for the observations made and described earlier in this paper.

Administration of Survey. To address the questions posed in this research study, a survey was constructed using the tool noted above (CEST) and given to students in engineering technology courses, and students forward it on to peers in a female engineering sorority.

Findings

The survey was completed by N=88 engineering technology students. The data was sorted and the various values from the CEST were used to determine if these students were more prone to having faith in their intuition or were more compelled to use cognition.

Demographics of Participants. First, we will examine the students that participated in this study, their demographics follow in Table 1.

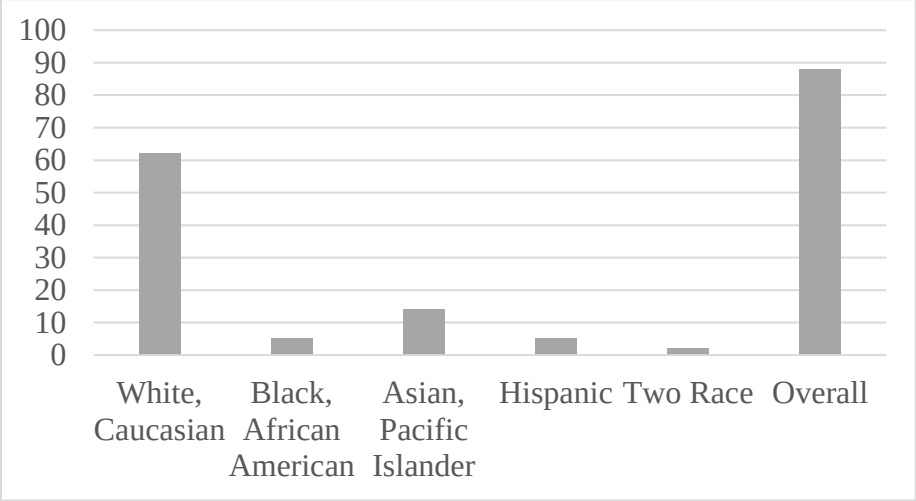

Table 1. Demographics of Study Population – By Race

Twenty-seven of the student population were female students, while the remaining students identified as to be male (this majority female sample may be attributed to students forwarding to colleagues in a sorority). As only one student selected “other” for gender, only female and male students will be used for data analysis and comparison. While the numbers vary, most engineering technology programs have between 7% and 14% female students [18].

Aggregate Result for Faith in Intuition and Need for Cognition. The student population consists of: 60 males, 27 females, and 1 other. The Figures 1 and 2 refer to the Average Faith in Intuition and Average Need for Cognition for the entire 88 students, respectively. When examining the two averages using a Likert scale of 1-7, Figure 1 shows that many of the responses were higher (4.5-5.0) than those shown in Figure 2 (2.7-3.0)

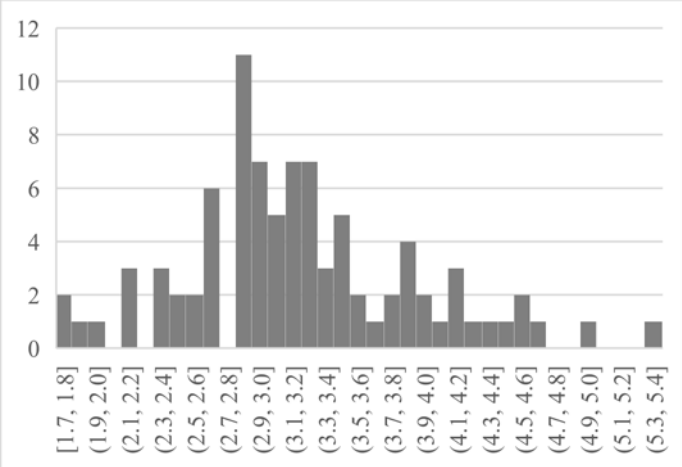

Figure 1: Aggregate – Faith in Intuition

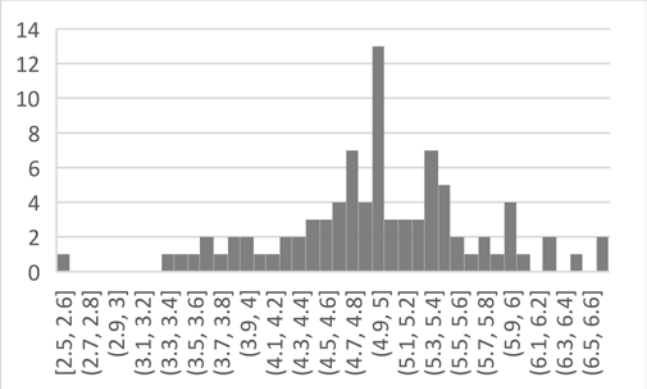

Figure 2: Aggregate – Need for Cognition

Examining Data by Gender - Female. Figures 3 and 4 show the results by gender, as only one respondent indicated other as gender only female data will be provided. Figures 3 and 4 refer to Female Faith in Intuition and Need for Cognition.

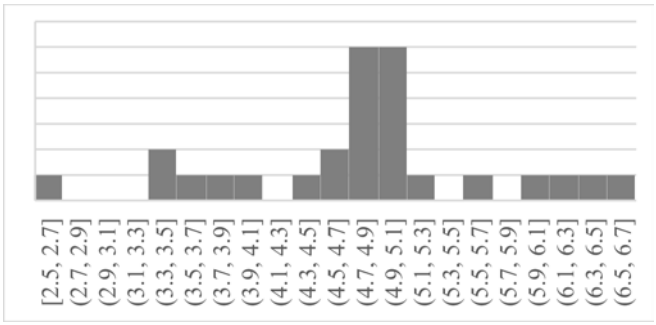

Figure 3: Female Average Faith in Intuition

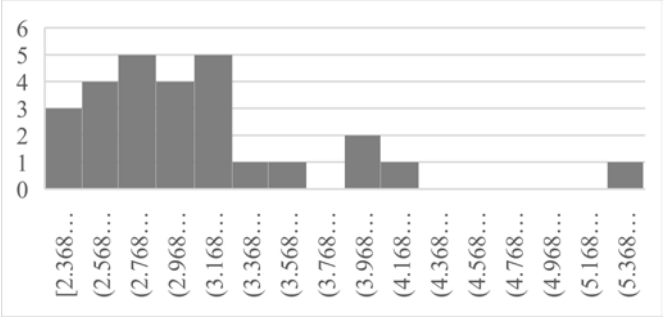

Figure 4: Female Average Need for Cognition

In comparison of Figures 3 and 4, it is noted that this study group rely more on intuition than on cognition.

Examining Data by Gender - Male. Figure 5 and 6 provide the data from male participants as they responded to the instrument. These figures provide information on Faith in Intuition and Need for Cognition

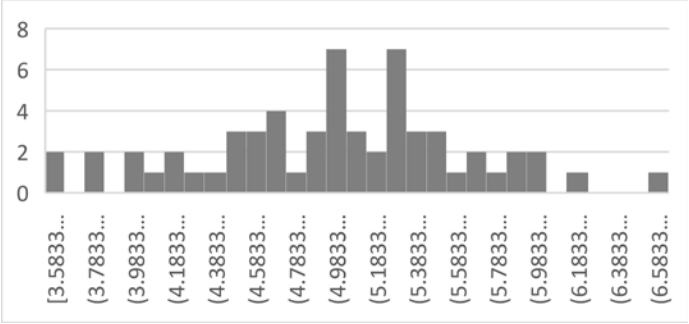

Figure 5: Male Average Faith in Intuition

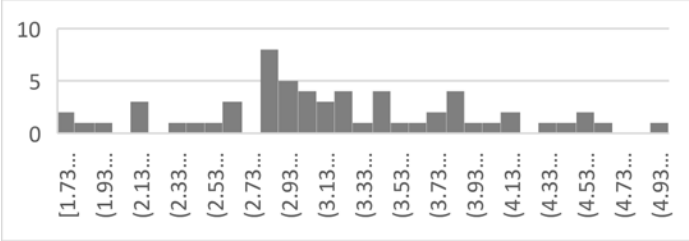

Figure 6: Male Average Need for Cognition

The comparison of the data in Figure 5 and 6 shows a greater distribution of preferences by male respondents. Careful comparison shows that these students also have a stronger preference for intuition than cognition.

Discussion/Conclusion

Overall, this research study sample had a low average need for cognition score. Females were slightly more likely to agree with situations that required their Use of Faith than Males. Males had an average score for Use of Faith of 5 (disagree) while the female average was 4 (neutral). Indicating that females may exhibit a tendency to be affected by math anxiety more so than their male counterparts.

The conclusions drawn will help to develop techniques to encourage students to have a more positive view of mathematics and to use mathematics for solving technical problems. A student's propensity towards a certain approach, in this case Use of Faith, greatly impacts the learning styles and techniques that should be used for these students. For example, as the example with the Dynamic's professor, when in doubt and under pressure students will provide an answer, they "feel" to be correct even when the answer deviates from what the correct answer is by a large margin. Therefore, learning styles and techniques in the classroom would need to be adjusted as to help these students instead utilize cognition instead of relying upon their Faith in Intuition. As engineering technology majors, the problems these students will face upon entering industry will impact the safety and well-being of many and such problems should not be answered based on intuition or faith the structure will hold. Rather these scenarios require a cognitive approach to ensure safety and reliability.

As such, helping these students learn to rely upon cognitive approaches, instead of their predisposed intuitive approach, while still in the classroom is crucial. Furthermore, helping the students overcome or at least manage their anxiety towards math will go a long way to ensuring these students think cognitively and methodically. In conclusion, the overall results of this research study will help to support future work on math anxiety and to develop methods to curb students' negative reactions to scenarios contributing to math anxieties.

Future Work

One of the coping mechanisms related to math anxiety is simply to avoid math. Such a mechanism has profound effects that impacts many a core life decision such as choosing a major in college and/or career upon graduation based on the likelihood of using math. A review of literature on students possibly avoiding certain college majors based on their anxiety towards math was found to be very little. Future work in investigating whether a person's math anxiety truly influences choice of college major and/or career is an avenue for looking into further.

Additionally, future work in implementing techniques or methods for decreasing a student's math anxiety while in college may help these students on a personal and professional level. As evidenced from this research study female students were slightly more likely than their male counterparts to rely upon intuition rather than cognition. As such, methods catered towards helping female students overcome or at least manage any math anxiety would be helpful in

remedying a student's decision to not pursue a certain avenue due to the likelihood of encountering math.

Survey Questions

The survey questions provided via email to the participants. The survey is intended to probe the participants thought process when facing various situations. The following survey questions were presented to participants using a Qualtrics platform. The questions follow the instrument and are grouped by the areas of cognition and inference.

Cognitive-Experiential Self Theory (CSET)

Epstein, Seymour, et al. "Individual differences in intuitive–experiential and analytical–rational thinking styles." Journal of personality and social psychology 71.2 (1996): 390.

R-Reverse

Need for Cognition

- I would rather do something that requires little thought than something that is sure to challenge my thinking abilities. (R)
- I don't like to have the responsibility of handing a situation that requires a lot of thinking. (R)
- I would prefer complex to simple problems
- I try to anticipate and avoid situation where there is a likely chance, I will have to think in depth about something. (R)
- I find little satisfaction in deliberating hard and for long hours. (R)
- Thinking is not my idea of fun. (R)
- The notion of thinking abstractly is not appealing to me. (R)
- I prefer my life to be filled with puzzles that I must solve. (R)
- Simply knowing the answer rather than understanding the reasons for the the answer to a problem is fine with me. (R)
- I don't reason well under pressure. (R)
- The idea of relying on thought to make my way to the top does not appeal to me. (R)
- I prefer to talk about international problems rather than to gossip or talk about celebrities.
- Learning new ways to think doesn't excite me very much. (R)
- I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.
- I generally prefer to accept things as they are rather than to question them. (R)
- It is enough for me that something gets the job done, I don't care how or why it works. (R)

- I tend to set goals that can be accomplished only by expending considerable mental effort.
- I have difficulty thinking in new and unfamiliar situations. (R)
- I feel relief rather than satisfaction after completing a task that required a lot of mental effort. (R)

Faith in Intuition

- My initial impression of people are almost always right.
- I trust my initial feelings about people.
- When it comes to trusting people, I can usually rely on my "gut feelings."
- I believe in trusting in my hunches.
- I can usually feel when a person is right or wrong even if I cant explain how I know.
- I am a very intuitive person.
- I can typically sense right away when a person is lying.
- I am quick to form impressions about people.
- I believe I can judge character pretty well from a person's appearance.
- I often have very clear visual images of things.
- I have a very good sense of rhythm.
- I am good at visualizing things.

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