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Approach to problem solving and use of intuition by engineering technology students

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Approach to Problem Solving and Use of Intuition by Engineering Technology Students

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Abstract

Engineering technology students often forgo a methodical approach of solving or answering questions on assignments or exams in favor of an intuition-based approach, emphasizing educated guessing (Broberg et al., 2008). Faculty observations have noted these student solutions often provide explanations, usually sans calculations, to support answers the students believe to be *reasonable* when in reality deviated from the correct answer. An extensive study was developed to assess several distinctions between student intuition and use of cognition in problem solving, as related to a generalized student population. The study was comprised of a survey and interview. The survey utilized two instruments, the Types of Intuition Scale (TIntS) and the Cognitive-Experiential Self Theory (CEST). The interview element was comprised of questions related to the student's background and personal experience with math phobia. Data provided by study participants responding to specific questions from the TIntS and CEST instruments allowed researchers to determine how likely students are to use intuition rather than analytical processes. The results of the study found these students prefer to approach problems using logic but tend to rely upon their intuition when problem solving, especially in unfamiliar and high-pressure scenarios. Furthermore, this paper is intended to enlighten educators and other related groups regarding the degree to which intuition is used as a means of solving problems, and the types of intuition generally involved, especially for engineering technology students. Thus, providing practitioners and administrators with a better idea of what these students may provide in response to homework or other problem-solving situations.

Keywords: thought process, mathematics, cognition, intuitive

Introduction

A clear delineation of the word intuition is richly debated with no one conclusive definition determined. Though, a generally accepted meaning defines intuition as "an understanding of the concept based on our feelings, knowledge and experience" (McCutcheon & Pincombe, 2001, p. 342). The use of intuition is abundant throughout society; however, this study shares the results of a survey focused on engineering technology students. While many define intuition differently, the general consensus involves an individual assessing the risk of a situation and making an educated guess, as opposed to utilizing a rational decision-making process often grounded in the use of mathematics (Harrison, 2016). In some cases, fields such as nursing, the use of intuition is critical in success (Chilcote, 2017). However, this is not always the case in science, technology, engineering, and mathematics (STEM) fields. For example, engineering field requires calculations and analysis for cases such as designing buildings, building bridges, or other infrastructure designs. Engineering technology students, upon graduation, will most likely venture into industry roles and obtain the title of Engineer. For such technical situations, possessing a mindset based on logical and rational reasoning would ensure that an engineer approaches a problem accurately with the result being a safe and sound product.

This research study was inspired by the observations of a professor teaching a Dynamics course to engineering technology students who observed that these students possibly relied on their intuition when faced with solving a problem, especially problems that were unfamiliar. Intuition often refers to a feeling or some premonition about the future whereas cognition often refers to the use of analytical or logical reasoning. While difficult to measure, researchers have developed and validated instruments to measure intuition and cognition. These instruments include the Types of Intuition Scale (TIntS) and the Cognitive Experiential Self Theory (CEST) measurement tool. The TintS is based on three distinct types of intuition: holistic, inferential, and affective (Pretz et al., 2014). The CEST is used to evaluate thinking styles and the preference of an individual to process information based on the two modes: intuitive experiential and analytical-rational (Epstein et al., 1996; Epstein, 2011). As such, the intent of this work was to provide insight on the types of and reliance on intuition favored and deployed by engineering technology students when solving new, unfamiliar problems.

Literature Review

Anecdotal observations made by faculty in the classroom discovered that students in engineering technology often choose to pick what they believe to be a reasonable response or as close to what they believe to be the correct answer to a question. The inspiration of this project and related projects was based on an observation by a professor teaching an engineering technology Dynamics course. Dynamics is the study of objects in motion and involves mathematical concepts and formulas used to compute scenarios of a theoretical and realistic phenomenon. Suspecting students were relying on intuition, the professor posed a problem that was designed to yield 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 previous knowledge and related experiences. As part of an exam, the professor asked the students to calculate the distance between the earth and moon. This question was chosen because the answer is not one that is easily observed or estimated, such as a question related to how fast a car must travel to reach a certain destination within a certain time span. Furthermore, the problem on the distance between the earth and moon required a calculation that was taught in the Dynamics course and was present in the students' course packet for the class. However, many of these students responded with unrealistic answers without providing calculations or rationale for their response. As a result, the possibility arose that these students guesstimated an answer based on what they felt to be correct, especially when faced with a problem outside of their usual problem-solving scenarios. Thus, this led the researchers to inquire about an individual's use of intuition.

Engineering technology is often erroneously combined with engineering, despite the two majors being decidedly different from one another in how their students think and approach problems. Although both engineering and engineering technology utilize engineering and scientific concepts to solve problems, engineering teaches from a theoretical perspective, whereas engineering technology teaches from a hands-on, applied perspective. In comparison to students from other similar engineering and science majors, researchers determined engineering technology students to be more attuned to sensory learning styles rather than intuitive learning styles preferred by engineering majors (Broberg et al., 2008). While conducting a review of literature regarding engineering technology students' use of intuition to solve a problem, little to no research was discovered. This shortage of research may be attributed to the fact that less than 2% of all engineering and engineering technology students combined are students in engineering technology (Roy, 2019). This shortage of research related to how engineering technology students solve problems in unfamiliar scenarios prompted this research.

Use of Intuition

Studies outside of academia supported the use of intuition-based decision-making for a variety of scenarios, such as crisis decision-making (Okoli & Watt, 2018), business decisions based on purchasing (Kaufmann et al., 2017), and the use of intuition by experts in a variety of fields (Zollo et al., 2017). While reviewing existing research on intuition, little was discovered on studies focusing on engineering technology students. In addition, the studies conducted did not have a specific focus on differences in gender or race. However, some interdisciplinary work had been done in other areas such as social and behavioral sciences and the arts, but not specifically in the area of engineering technology (Davis-Floyd & Arvidson, 2016). The interdisciplinary work discovered in that interdisciplinary compilation is a summary of findings and the perspective of intuition from a cognitive and psychological viewpoint. Research by Epstein (2011) shared the belief that an individual's use of intuition is based upon experience. The intent of this work was to provide insight on the types of intuition and reliance on intuition deployed by engineering technology students when solving new problems. The supposition that engineering technology students rely upon their intuition will lay the foundation for future research studies to delve deeper into this particular aspect of thinking by these students. This may then further lay out a rationale for larger studies in this or similar groups of students with the intent of working with these students in ways that suit their way of problem solving and helping them to problem solve productively.

Female Students

Researchers Sinclair & Ashkanasy (2005) have investigated whether students' identified gender has an impact on their intuition; the findings indicated that females tended to access intuition more so than their male counterparts (Sinclair & Ashkanasy, 2005). Students who pursued the engineering technology route tended to prefer working with their hands, such as physically testing a material's hardness using equipment in a material testing laboratory. In contrast, engineers tended to pursue the theoretical route of utilizing computer simulations. Therefore, it would be useful to know whether female engineering technology students also follow this trend or if they rely more on learned academic knowledge to solve a problem when compared to their male engineering technology counterparts. The authors of this research paper, in pursuit of inquiring further into this question, included it as part of the research study.

College Students and Math Anxiety

A study on how prevalent math anxiety is among college students was conducted at The Ohio State University and involved 652 male and female college students who were enrolled in two math courses and one psychology course (Betz, 1978). The students were tested on the Math Anxiety scale, the A-Trait scale, and Spielberger's Test Anxiety Inventory. The study results discovered that avoiding math courses can begin early and that anxiety was a common thread among answers related to math exams. Furthermore, higher levels of math anxiety were related to lower math scores, and higher test anxiety. Additionally, math anxiety was also discovered to be more likely to occur among women than men and for students with an inadequate high school background (Betz, 1978).

Survey Instruments

While researching various methods of measuring intuition, several different methods have been used: Rationality-Experientiality Inventory (Björklund & Bäckström, 2008) and Preference for Intuition/Deliberation Scale (Betsch & Iannello, 2009), as well as others. The instruments that were determined to be best for a student population in engineering technology were the TIntS and CEST scales (Epstein et al., 1996). These two scales were chosen for this research study because they were among the more comprehensive means of measure for the different types of intuition, while also providing an insight into respondent's preference for use of one type of intuition over another. In addition, this instrument measured whether the respondents were prone to thinking intuitively or rationally.

Types of Intuition Scale (TIntS)

The TIntS are one of the most comprehensive measures of intuition, compared to other measures. The TIntS include self-reported preferences, sorting the responses to 29 questions into three different types of intuition as defined by Pretz and Totz (2007). The three different types of intuition as defined by these authors were: holistic intuition, inferential intuition, and affective intuition. *Holistic intuition* involves judgements based on largely non-analytical processing, essentially pulling experiences together into a whole. *Inferential intuition* is the practice of building decisions or answers on life experiences and automated learned actions over time, while *affective intuition* is emotionally based reactions to decisions that are made (Pretz & Totz, 2007). The survey questions abide by the TIntS as shown in Appendix Table A1, and is comprised of eight Reversed, five Holistic-Big Picture, three Holistic-Abstract, twelve Inferential, and nine Affective items. The TIntS questions were referenced from articles from the Journal of Behavioral Decision Making and are used to assess how likely participants were to rely upon their intuition when faced with a scenario requiring problem solving (Pretz et al., 2014).

Cognitive-Experiential Self Theory (CEST)

The CEST evaluates thinking styles and was developed by psychologists who determined that there are two different modes an individual will use to process information: intuitive-experiential and analytical-rational (Epstein et al., 1996). The CEST determines the preferred type of thinking

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utilized by individuals in a variety of settings in order to ascertain whether the individual is prone to relying upon their intuition based on learned experiences, or are more likely to employ a rational, logical approach (Epstein, 2011).

Research Questions

This research study aimed to determine how likely students pursuing an engineering technology degree were to rely upon their intuition to solve problems.

- How much do engineering technology students rely on their intuition for solving problems?
- What type of intuition do students in engineering technology rely upon to solve problems?
- Does gender play a role in students' reliance upon intuition?
- Do engineering technology students prefer problems requiring in-depth thinking or questions that are straightforward?

Methods

This descriptive research study utilized an electronic survey element to glean whether or not students are prone to using logic or if their thinking was based more on intuition and if so, what type of intuition. A second element of this research study utilized an interview element to glean students' personal experiences with math and STEM courses, in general (Taleyarkhan et al., 2021). Since this research study examined several different perspectives, the results were used to guide and refine what future research studies should further investigate. Previous researchers had developed and validated two survey instruments, TIntS (Pretz et al., 2014) and CEST (Epstein, 2011). The full list of questions used from the TIntS and CEST instrument scales that were used in the survey portion of the study are shown in Appendix Table A1 and A2, respectively. Additional survey questions consisted of general demographic questions relating to gender, race, and zip code and were framed in a way which obtained a participant's basic background while also preserving the individual's anonymity.

The procedures of acquiring and analyzing the subject data was conducted objectively. Students were required not to reveal any personal or identifying information such as their name or names of others during the survey and interview components. When analyzing the data, each participant was assigned a numerical identity to preserve research objectivity and anonymity of the participant.

A few impediments related to participant recruitment were observed. Due to difficulty in recruiting the full 20 engineering technology students needed for this study, any student (regardless of major) was allowed to partake in the study. As such, although the majority (15 out of 20) participants in this study were from engineering technology, a small number were from majors outside of engineering technology. This was deemed allowable due to the added opportunity to compare engineering technology students' experiences to their peers from other college majors. The results of the comparison may help to discover future research study directions in analyzing this unknown population of engineering technology students.

Sample and Data Collection

Undergraduate participants from a Midwestern university (*n* = 223, 49 female and 174 male) located in the United States of America (USA) were provided access to the electronic survey via an email embedded with a link for participants to access the untimed survey administered using the Qualtrics platform. The survey was emailed to students majoring in engineering technology and related degrees. The survey was also distributed to a female sorority comprising both engineering technology and engineering students. The interview component comprised a total of 20 participants and took place in-person in a small conference room on the University campus. The interview protocol was designed to be completed in approximately 30 minutes and upon completion of both the survey and interview, participants received a $10 Starbucks gift card.

The research questions for this study were investigated by constructing an approximate 15-minute survey using the tools noted above (TIntS and CEST) and distributing the survey via email to undergraduate students primarily in engineering technology majors and majors related to technical/engineering fields. The interview component was designed to be completed in 30 minutes and comprised 20 participants, primarily in engineering technology or related majors, and most of which are female and come from an underrepresented minority. Recruitment was performed by circulating a recruitment email to participants to first complete the survey before participating in the interview portion of the study.

Empirical Model

The data was downloaded from Qualtrics as a Microsoft Excel spreadsheet for data and statistical analysis. The researchers examined the survey data first by looking at the aggregate responses of engineering technology majors and their responses to questions in the instrument. This was followed by an examination of responses grouped based on gender in order to determine if a correlation between subgroups existed. The responses to the TIntS and CEST survey questions were collected using the Likert scale and converted to numerical format ranging from 1-7, where 1 corresponded to strongly agree and 7 was strongly disagree. This conversion to a numerical format was done to accommodate statistical analysis of the data. Respondents that did not respond to all questions were eliminated from the sample. The data collected for this study (*n* = 272) resulted in 223 sets of complete data from individual participants. The interview component was completed in person and voice recorded. The interview recordings were then converted to a transcript form for qualitative analysis. Recurring themes and frequent word usage were manually performed for the selected interview questions examined for this research study paper.

Findings

The research study findings provided an insight into the participants' thought processes when faced with a particular scenario. Each of the following sections provide different details and insights into how engineering technology students utilize intuition in their lives. The 223 student participants consisted of 49 females and 174 males. As a note, participants were prompted to state their race/ethnicity and the results consisted of 153 White/Caucasian, 33 Asian/Pacific Islander, nine Black/African American, 16 Hispanic, 9 of Two Race, and 3 of Three Race. Due to the limited racial variance, comparisons regarding race and ethnicity were not examined.

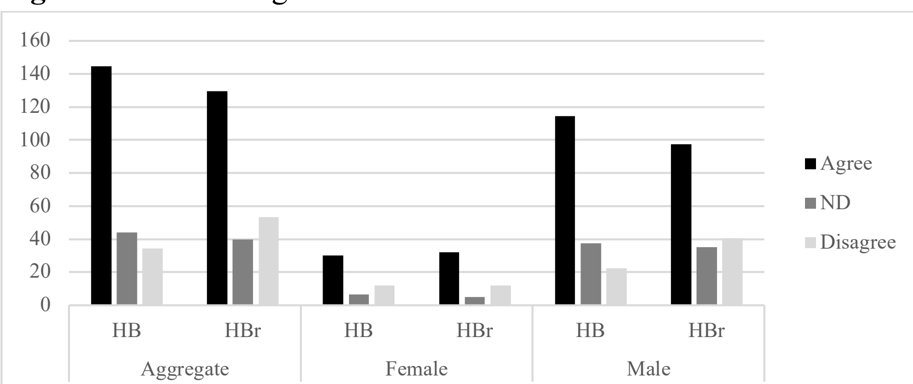
Intuition Survey Results

The Intuition Survey, based on the TIntS survey, comprised of 29 questions designed to ascertain whether an individual relies on or utilizes their intuition and if so, what type of intuition the individual employs (Pretz et al., 2014). The questions are divided among the four different types of intuition: Holistic Big Picture, Holistic Abstract, Inferential, and Affective. The survey responses for the participants were based on the Likert Scale (1-7). The data analysis combined and grouped the responses based on Agree, Neither Agree nor Disagree, and Disagree.

Holistic Big Picture Response Results

The Holistic Big Picture (HB) survey questions were designed to determine whether participants focus on the big picture when problem solving. The reverse Holistic Big Picture (HBr) questions refer to whether participants focus on the details when problem solving. The data results shown in Figure 1 include the participants' answers to HB and HBr questions as to how agreeable the participants are to that type of thinking. Overall, the data shown in Figure 1 illustrated participants focused more on the big picture (HB) when problem solving as indicated across the aggregate, female, and male participants. However, for the questions where participants were asked to focus on the details and break up the problem, they were still able to do so.

Figure 1. Holistic Big Picture vs. Details

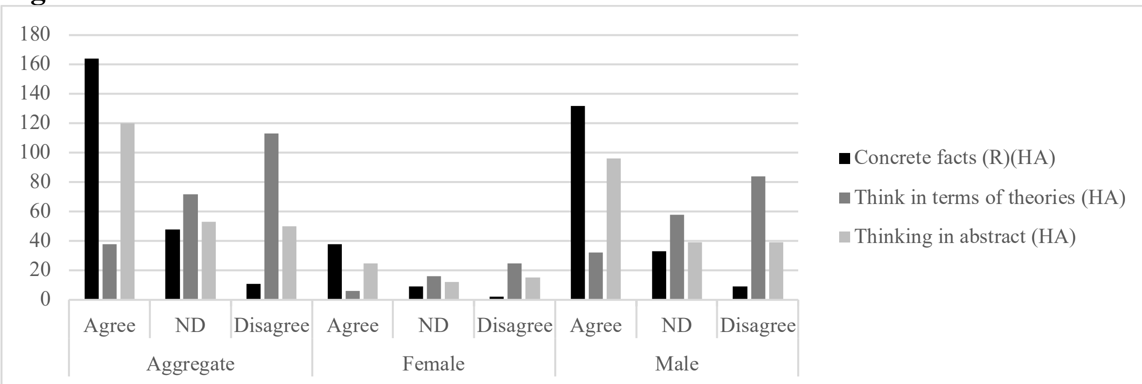


Note. HB = Holistic Big Picture; HBr = Reverse Holistic Big Picture; ND = Neither Agree nor Disagree.

Holistic Abstract Response Results

The Holistic Abstract (HA) questions consisted of three main questions designed to ascertain whether individuals prefer: concrete facts over abstract theories; thinking in terms of theories rather than facts; and thinking in abstract terms. The (R)(HA) questions refer to reverse (R) Holistic Abstract (HA) questions indicating a preference for concrete facts instead of abstract theories. Results of the data are reflected in Figure 2, which indicate that the aggregate population prefers concrete facts (R)(HA) over abstract theories, followed by thinking in abstract terms. Both females and males followed this trend of the majority preferring concrete facts (R)(HA), followed by a large amount disagreeing with preferring concrete facts.

Figure 2. Holistic Abstract

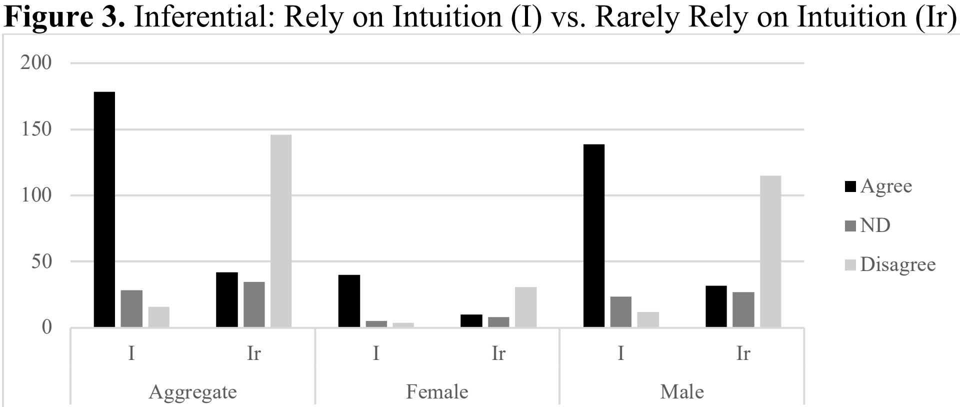


Note. HA = Holistic Abstract; (R)(HA) = Reverse Holistic Abstract; ND = Neither Agree nor Disagree.

Inferential Response Results

The Inferential (I) questions examined whether individuals rely upon their intuition when problem solving. Portions of the intuition questions focused on whether individuals can provide support for their intuitive responses with logical reasoning and if an individual relies on past experiences when problem solving. The one reverse question (Ir) ascertained whether participants rarely trusted their intuition in their area of expertise. In other words, if participants agreed with the (I) questions, they rely upon their intuition when problem solving. If they agree with the reverse (Ir) questions, then the participants rarely rely upon their intuition (Ir) when problem solving. Therefore, if a participant agreed with the (I) questions, then they disagreed with (Ir) questions and vice versa. The data results shown in Figure 3 show that the aggregate population agreed with the inferential (I) questions of relying upon their intuition when problem solving. Female and male participant responses followed the same trend as the aggregate population.

Figure 3. Inferential: Rely on Intuition (I) vs. Rarely Rely on Intuition (Ir)

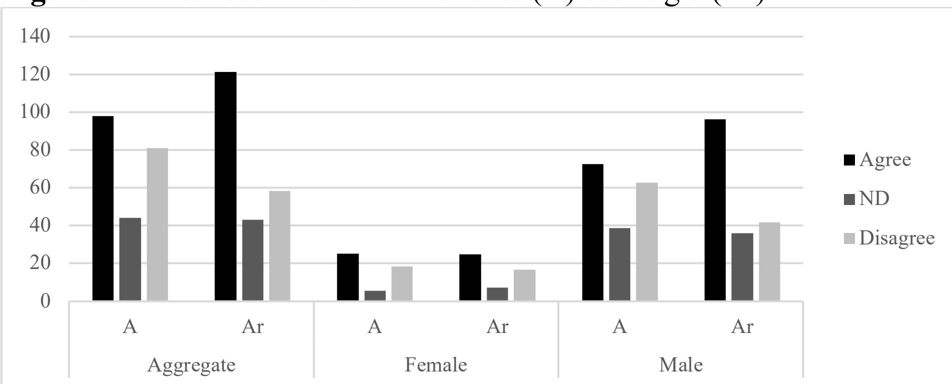


Note. I = Inferential; Ir = Reverse Inferential; ND = Neither Agree nor Disagree.

Affective Response Results

The Affective (A) questions ascertained whether an individual relies on *emotion/emotional hunches* when problem solving. The affective reverse (Ar) questions were designed to seek whether an individual rarely involves their emotions when problem solving. Figure 4 displays the data results for the aggregate population, which reflected that a majority of the participants did not allow their emotions to override their *logic* or to dictate their decision making. The male student participants followed the same answer/response trends for the aggregate population with approximately 73 males out of a total of 174 male participants agreeing that they rarely involve their emotions when problem solving. However, the female student participants were approximately equal in one half agreeing that emotions play a role in decision making while the other half say emotions do not play a role in decision making.

Figure 4. Affective: Emotional Hunches (A) vs. Logic (Ar)



Note. A = Affective; Ar = Reverse Affective; ND = Neither Agree nor Disagree.

Intuition Survey Summary Results

Table 1 provides an overview of the Intuition type questions, based on the TIntS survey, and shows average result values used to produce Figures 1 to 4. The average values for aggregate, female and male correspond to the average number of participants who Agree, Neither Agree nor Disagree, or Disagree. The gender average values help to show which particular gender Agree, Neither Agree nor Disagree, or Disagree with a particular area of Intuition. From the average results across all three of the main Intuition survey questions, the largest value showed that on average approximately 179 out of a total of 223 participants agreed with Inferential (I) questions, indicating that the participants do utilize their intuition when problem solving. The Holistic-Abstract (HA) questions were deemed too few and different among one another to be able to compare their average values in Table 1.

Table 1. Average Intuition Results for Three Intuition Areas

Type of Intuition	Aggregate		Female		Male	
Holistic-Big Picture	**HB**	**HBr**	**HB**	**HBr**	**HB**	**HBr**
Agree	144.67	129.50	30.33	32.00	114.33	97.50
Neither Agree nor Disagree	44.00	40.00	6.67	5.00	37.33	35.00
Disagree	34.33	53.50	12.00	12.00	22.33	40.67
Inferential	**I**	**Ir**	**I**	**Ir**	**I**	**Ir**
Agree	178.55	42.00	40.00	10.00	138.55	32.00
Neither Agree nor Disagree	28.64	35.00	5.18	8.00	23.45	27.00
Disagree	15.82	146.00	3.82	31.00	12.00	115.00
Affective	**A**	**Ar**	**A**	**Ar**	**A**	**Ar**
Agree	97.80	121.25	25.20	25.00	72.60	96.25
Neither Agree nor Disagree	44.00	43.25	5.40	7.25	38.60	36.00
Disagree	81.20	58.50	18.40	16.75	62.80	41.75

Note. HB = Holistic-Big Picture; HBr = Reverse Holistic-Big Picture; I = Inferential; Ir = Reverse Inferential; A = Affective; Ar = Reverse Affective

Cognition

The Cognition survey questions were comprised of two main modes: intuitive-experiential and analytical-rational (Epstein et al., 1996). The questions were designed to ascertain how individuals approach problems, and whether they are prone to relying upon their intuition and past experiences or if they are more analytical and logical thinkers. The questions analyzed were based on questions with similar themes that could be compared to what was shown for Intuition and that apply to engineering technology students and how they think during problem solving. The data was analyzed using Microsoft Excel and the top 10 responses with the highest amounts for a particular question were used due to the large volume of responses that were either agreeing or disagreeing for a certain situation. An additional four questions were also used for comparison based on their similar theme to both Intuition and the subsequent interview question section of this study.

Thinking In-Depth

Engineering technology majors, in addition to being visual learners, are believed to enjoy solving problems by using new and tried methods (Broberg et al., 2008). The following questions shown in Table 2 highlight a series of questions from the CEST survey that were among the Top 10 responses with the highest values. The questions are grouped around thinking and situations which thinking a great deal and in-depth are required. The aggregate data results reveal that 84% disagree with the question (TiD Q4) that thinking or learning in new ways is not exciting.

Table 2. CEST Thinking In-Depth Questions (TiD Q)

Group	Scale	TiD Q1	TiD Q2	TiD Q3	TiD Q4	TiD Q5
Aggregate	Agree	46	34	32	17	36
	Neither Agree nor Disagree	28	31	37	18	28
	Disagree	149	158	154	188	159
Female	Agree	9	7	5	3	9
	Neither Agree nor Disagree	3	2	5	1	3
	Disagree	37	40	39	45	37
Male	Agree	37	27	27	14	27
	Neither Agree nor Disagree	25	29	32	17	25
	Disagree	112	118	115	143	122

Note. TiD Q1 = I would rather do something that requires little thought than something that is sure to challenge my thinking abilities (Reverse); TiD Q2 = I try to anticipate and avoid situation where there is a likely chance, I will have to think in depth about something (Reverse); TiD Q3 = Thinking is not my idea of fun (Reverse); TiD Q4 = Learning new ways to think doesn't excite me very much (Reverse); and TiD Q5 = It is enough for me that something gets the job done, I don't care how or why it works.

CEST Intuitive Responses

The questions related to whether an individual is intuitive and trusts their hunches aligned with the TIntS Intuition survey questions. The responses shown from the CEST survey questions in Table 3 further supports that the students do rely upon and utilize their intuition and emotional hunches in situations. For the female participants, 76% agreed they trust their hunches, 73% agreed they are an intuitive person and 76% agreed that the notion of thinking abstractly is appealing. For the male students, 75% agreed they trust their hunches, 80% agreed they are an intuitive person, and 67% agreed that the notion of thinking abstractly is appealing.

Table 3. CEST Intuitive Questions (I Q)

Group	Scale	I Q1	I Q2	I Q3
Aggregate	Agree	168	176	34
	Neither Agree nor Disagree	37	31	35
	Disagree	18	16	154
Female	Agree	38	36	7
	Neither Agree nor Disagree	4	6	4
	Disagree	7	7	38
Male	Agree	130	140	27
	Neither Agree nor Disagree	33	25	31
	Disagree	11	9	116

Note. I Q1 = I believe in trusting my hunches; I Q2 = I am a very intuitive person; and I Q3 = The notion of thinking abstractly is not appealing to me (Reverse).

CEST Questions and Interview Question Similarity

The CEST questions chosen to be compared to the interview questions were based on which had a high number of responses and were of particular interest for this student population that related to how these students think in relation to complex type problems, unfamiliar situations, and reasoning under pressure. The interview questions were also specifically chosen to complement the CEST questions.

The four CEST questions used to compare are:
1. I prefer my life to be filled with puzzles that I must solve.
2. I have difficulty thinking in new and unfamiliar situations.
3. I don't reason well under pressure.
4. Simply knowing the answer rather than understanding the reasons for the answer to a problem is fine with me.

Table 4 shows these questions and the response rate by the participants for this study. The first three questions relate to how these students perceive situations that might be complex and unfamiliar. The response for the participants preferring their life to be filled with puzzles they must solve has a large majority of the aggregate (70%) agreeing. The survey question on having difficulty thinking in new and unfamiliar situations, is very similar to an interview question asked. In particular, the responses from the CEST survey indicated that participants do not have difficulty thinking in new and unfamiliar situations. Similarly, the question on whether a participant would not reason well under pressure showed data results of a large amount disagreeing, which indicated that these participants believed they do reason well under pressure.

Table 4. CEST and Interview Question Comparison (CESTQ)

Group	Scale	CESTQ1	CESTQ2	CESTQ3	CESTQ4
Aggregate	Agree	156	77	90	29
	ND	38	43	23	26
	Disagree	29	103	110	168
Female	Agree	31	15	27	8
	ND	7	7	4	2
	Disagree	11	27	18	39
Male	Agree	125	62	63	21
	ND	31	36	19	24
	Disagree	18	76	92	129

Note. CESTQ1 = I prefer my life to be filled with puzzles that I must solve (Reverse); CESTQ2 = I have difficulty thinking in new and unfamiliar situations (Reverse); CESTQ3 = I don't reason well under pressure (Reverse); and CESTQ4 = Simply knowing the answer rather than understanding the reasons for the answer to a problem is fine with me (Reverse).

As shown for the aggregate population, 110 disagreed but 90 participants agreed. Indicating that although a large number agree (49%) that they reason well under pressure, a still sizable number of participants (40%) disagree that they reason well under pressure. The last question in Table 4 comprises another similar interview question relating to whether participants would rather know the answer to a problem and not the reasons behind the answer. The results showed that these participants would prefer to know why a particular answer is correct rather than just knowing what the answer is.

Interview Results

The interview portion of this Math Anxiety research study employed 20 participants and was designed for female and minority students, preferably from engineering technology (Taleyarkhan et al., 2021). The participants comprised 15 from engineering technology, four participants from engineering and one from liberal arts (film and video). Of the 20 participants, four were male and 16 were female.

The interview questions were designed to delve into a participant's home life and personal experiences with math, accompanied by several scenario-based questions comprising a mix of mathematical and peer pressure scenarios. Due to the problem solving and mathematical scope of this research, only questions relating to math, and specifically problem solving, were analyzed, and compared to select responses from the Intuition and Cognition Survey results. This allowed the researchers of this paper to triangulate the results from the survey instruments and interview questions to obtain a comprehensive view of how these students think in a variety of scenarios. The results from the interview included analysis of the aggregate interview population and then localized into reviewing and comparing female and male students in Engineering Technology and other engineering students.

The following three questions were used from the Interview:

1. Describe STEM related classes.
2. Exam day for math class. You have prepared for this test for two weeks; how do you feel?
3. Assume you have never seen this problem: *Find the value of cos75°*. How do you react? What is your thought process when seeing an unfamiliar math problem?

The summary of the most frequent words used to describe STEM related classes discovered the majority of participants believed the classes to be challenging and hard. Though, the engineering technology students believed that STEM classes that are hands-on offer the most practical benefit and teach learning skills most applicable for the real world. The four engineering students indicated that STEM courses were difficult, with one respondent saying that they were "fun and ok" but could be challenging in different ways.

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. Female engineering technology students stated they would feel good but still a little nervous, which may have caused them to 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". Female engineering students stated they would feel good and not worried. Though, one respondent stated they would be nervous that the content they studied might not be what was tested on the exam. Male engineering technology students were divided between half stating they would be nervous and anxious, while the other half stated they would feel confident they would know the material.

The responses for how a participant would react upon seeing an unfamiliar math problem were universal across both gender and majors. 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 to determine the correct answer.

Survey Versus Interview Results

The majority of the interview results coincided with the results from the survey, though in some areas they were diverged. First, students do draw upon past experiences to solve problems, prefer working in a logical fashion, and do not shy away from complex problems. However, students do panic when placed in an unfamiliar situation, especially if that situation is in an exam setting. Though after the initial panic, students will try to reason through the problem. The results for the CEST question referenced from Table 4, of whether an individual reasons well under pressure, showed a majority (49%) agreed they do reason well under pressure. From the interview results, it is supported that these students may not initially reason well under pressure, especially for a mathematical examination involving unfamiliar problems. Though, after the initial panic, the students do try to think about the problem and attempt to draw on previous knowledge indicating that these students are logical thinkers but the results from the TIntS survey indicates they also rely on their intuition when problem solving. Furthermore, the degree of confidence students felt in regard to the question on studying two weeks in advance for a math exam may have a direct relationship to the likelihood of whether they may rely upon their intuition in unfamiliar or stressful situations. A student who felt less confident may feel inadequate cognitively which may then make them more inclined to think intuitively when attempting to complete the exam. As such, this supposition may lay the basis for future research studies to correlate whether there may be a relationship between a student’s confidence and use of intuition. The findings may then help researchers determine whether researching a student’s intuitive responses should bear further research or if another area will need further probing.

Discussions

Based on the data generated from this initial small study, it was discovered that engineering technology students often rely upon their intuition for solving problems. However, based on their preferred type of intuition (Holistic-Abstract and Affective), students prefer taking logical steps toward problem solving. This discrepancy between the findings of the students’ preference for logical thinking but relying upon their intuition in real-life situations, indicate that engineering technology students prefer to use rational, methodological approaches but ultimately rely upon their intuition when faced with unfamiliar scenarios (Yeh et al., 2020). This is further supported based on the results of the interview question on facing an unfamiliar problem, where students would initially panic and then try to reason through the problem using past/related material. When considering gender differences, it was discovered female students rely upon intuition slightly more than their male counterparts. Although both females and males preferred Holistic-Abstract and

Affective types of questions, females also slightly agreed with Holistic-Big Picture type questions more than males.

The results of this survey suggest that engineering technology students relied on Holistic Intuition, both Big Picture and Abstract. The overall results of the three chosen interview questions showed that these students largely believed STEM courses are difficult and challenging but believe they are applicable and offer skills to succeed in the real world. In regard to mathematical problems and exams, the students would be nervous when studying for a math exam, regardless of how far in advance they studied for the math exam. Furthermore, when faced with an unfamiliar math problem, the participants would initially panic but would then intuitively rely on past knowledge to help them reason through the problem to obtain an answer they hope is correct.

Based on this initial investigation, engineering technology students stated they prefer problems requiring in-depth thinking over those not requiring much thought. However, though the students enjoy in-depth thinking they appeared to abstain from such analytical processes upon reaching a state of confusion requiring them to rely instead upon their intuition to solve said in-depth problems. Therefore, the supposition forms that these students prefer to think analytically and deeply but lack the proper sensory cranial training to continue the analytical thinking path upon reaching a point of the unfamiliar that forces them to think intuitively instead.

Conclusion

The data used for this research study was a small sample of the many engineering technology students throughout USA. As such, the findings from this research study may help to guide in outlining future studies which may be conducted on a much larger scale. Future work could entail investigating undergraduate engineering technology students from other institutions of higher learning throughout the country. The noteworthiness of this research study in delving into how engineering technology students approach problems and their reliance on intuition is groundbreaking. The results of this research study provide a preliminary insight into the extent that engineering technology students depend upon their intuition but also the type of intuition they utilize. The type of intuition used by these students shows additional insight into how these students precisely approach or would rather approach problems. As such, the revelation that engineering technology students are more intuitive rather than cognitive could potentially help researchers and faculty in modifying teaching methods in order to discourage a student's reliance upon intuition. Furthermore, researchers may delve deeper in examining and investigating the extent engineering technology students rely upon intuition and what situations may trigger an intuitive response rather than that of a cognitive approach (Davis et al., 2021). Accordingly, once the thought processes and intricacies of how these students approach problem solving are conclusive, appropriate modifications to engineering technology course curriculums may be carried out to properly cater and prepare these students to solve any type of problem they may encounter.

Theoretical Implications

The implications of this initial study on how engineering technology students approach problem solving would greatly impact the curriculum currently used for teaching these students. Engineering technology and engineering students often share a near-identical curriculum format for learning the same engineering and scientific principles. The main differentiation is that engineering teaches from a more theoretical standpoint using textbooks and computer simulations to showcase engineering and scientific principles. Contrasted, engineering technology students are taught using textbooks and hands-on laboratory activities to showcase engineering and scientific disciplines. As such, the hands-on activities allow engineering technology students, who are more sensory prone learners, to actually view the science in motion (Broberg et al., 2008). Whereas engineering students, who are more intuitive learners, are taught to view science in a more abstract, theoretical mindset (Broberg et al., 2008). A summary of the findings of this initial research study found that engineering technology students preferred to pursue analytical and methodological approaches to problem solving but when in an unfamiliar or high-pressure situation rely on their intuition. The high-pressure scenario from this study which helped come to this conclusion was a mathematical exam.

Practical Implications

Mathematics is a theoretical learning concept and as stated, engineering technology students are largely taught using hands-on activities to actually view engineering and scientific phenomena at work. Furthermore, mathematics is often taught by faculty outside of the students own college and therefore the learning methods and curriculum may oftentimes differ greatly from the way the majority of the courses engineering technology students are taught. As such, when placed in a situation which does not allow for these visual learners to view the problem may then force these students to eschew their preferred analytical thinking to instead rely upon intuition to solve the problem. Therefore, the implications based on this initial study indicate that the curriculum used to teach these visual, sensory learners may need to be adjusted when teaching a theoretical concept such as mathematics. As such, injecting how to think theoretically or in abstract terms may help engineering technology students adjust their thought process when placed in a situation to solve a problem for which a mental picture cannot be constructed.

Limitations

The study evaluated data from a limited pool of participants; survey data consisted of $N = 223$ and the interview data consisted of 20 participants. Although there were enough participants to formulate a study and tabulate data, it is not enough to provide conclusive evidence in favor of a particular hypothesis. Furthermore, the data was provided from students located from just one USA Midwestern university and as such the findings from this study would not be a fair representation of the engineering technology student body at large. As such, the next phase of future research for studying engineering technology student's approach to problem solving should evaluate a larger number of participants ($N = +500$) from not only the Midwestern university used for this study but from universities/colleges from other regions of the United States of America and abroad. The larger number and broader geographical representation of participants will allow for researchers to compare/contrast the data of this wider audience to the initial findings of this research study.

Future Research

A larger audience of participants from varying backgrounds would allow for the opportunity of discovering new factors which may contribute to why engineering technology students rely upon intuition in certain scenarios. Additionally, a comparison of how engineering technology versus engineering students approach problem solving would allow an insight for whether engineering students, who are taught on a more theoretical mind framework, would react in a similar fashion in the same scenarios. This comparison may additionally help in future research for formulating a revised curriculum for teaching engineering technology students on how to approach theoretical problems using analytical thought processes instead of reverting to their intuitive methods of solving theoretical problems in unfamiliar/high-pressure scenarios. Ultimately, by pursuing further research on how engineering technology students approach solving problems in a variety of scenarios, especially that of the theoretical, would be beneficial for equipping these students to graduate and become competent and reliable engineers.

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Appendix A1: Types of Intuition Scale (TIntS) Questions

1. When tackling a new project, I concentrate on big ideas rather than the details. (HB)
2. I trust my intuitions, especially in familiar situations. (I)
3. I prefer to use my emotional hunches to deal with a problem, rather than thinking about it. (A)
4. Familiar problems can often be solved intuitively. (I)
5. It is better to break a problem into parts than to focus on the big picture. (R) (HB)
6. There is a logical justification for most of my intuitive judgments. (I)
7. I rarely allow my emotional reactions to override logic. (R) (A)
8. My approach to problem solving relies heavily on my past experience. (I)
9. I tend to use my heart as a guide for my actions. (A)
10. My intuitions come to me very quickly. (I)
11. I would rather think in terms of theories than facts. (HA)
12. My intuitions are based on my experience. (I)
13. I often make decisions based on my gut feelings, even when the decision is contrary to objective information. (A)
14. When working on a complex problem or decision I tend to focus on the details and lose sight of the big picture. (R) (HB)
15. When making decisions, I value my feelings and hunches just as much as I value facts. (A)
16. I believe in trusting my hunches. (A)
17. When I have experience or knowledge about a problem, I trust my intuitions. (I)
18. I prefer concrete facts over abstract theories. (R) (HA)
19. When making a quick decision in my area of expertise, I can justify the decision logically. (I)
20. I generally don't depend on my feelings to help me make decisions. (R) (A)
21. I've had enough experience to know what I need to do most of the time without trying to figure it out from scratch every time. (I)
22. If I have to, I can usually give reasons for my intuitions. (I)
23. I prefer to follow my head rather than my heart. (R) (A)
24. I enjoy thinking in abstract terms. (HA)
25. I rarely trust my intuition in my area of expertise. (R) (I)
26. I try to keep in mind the big picture when working on a complex problem. (HB)
27. When I make intuitive decisions, I can usually explain the logic behind my decision. (I)
28. It is foolish to base important decisions on feelings. (R) (A)
29. I am a *big picture* person. (HB)

Note. R = Reversed, HB = Holistic-Big Picture, HA = Holistic-Abstract, I = Inferential, A = Affective
Source. Pretz et al., 2014.

Appendix A2: Cognitive-Experiential Self Theory (CEST) Need for Cognition Questions

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

18. I have difficulty thinking in new and unfamiliar situations. (R)
19. I feel relief rather than satisfaction after completing a task that required a lot of mental effort. (R)
20. Faith in Intuition
21. My initial impression of people are almost always right.
22. I trust my initial feelings about people.
23. When it comes to trusting people, I can usually rely on my *gut feelings*.
24. I believe in trusting in my hunches.
25. I can usually feel when a person is right or wrong even if I can't explain how I know.
26. I am a very intuitive person.
27. I can typically sense right away when a person is lying.
28. I am quick to form impressions about people.
29. I believe I can judge character pretty well from a person's appearance.
30. I often have very clear visual images of things.
31. I have a very good sense of rhythm.
32. I am good at visualizing things.
33. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities. (R)
34. I don't like to have the responsibility of handling a situation that requires a lot of thinking. (R)

Note. R = Reverse.
Source. Epstein et al., 1996.

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