Engineering State of Mind Instrument: A tool for self-assessment

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Introduction

Undergraduate student recruitment and retention in engineering continue to be an important topic in higher education, especially as it relates to diversity and inclusion. In 2016 about 45% of freshmen indicated they planned to major in an S&E field (up from about 8% in 2000); [1]. While the number of degrees awarded in the STEM fields has increased steadily in the past 10 years, only 16% of bachelor's degrees awarded were engineering degrees.

Best practices (i.e. mentorship, pedagogical changes, climate change, and awareness) have been discovered and implemented throughout the country providing great outcomes (increased retention and diversification of student population) and even meeting societal objectives of producing more engineers[2, 3]. However, universities continue to struggle to provide a flow of engineering talent to fulfill the needs of industry and research spaces.

Limited investigation has been conducted focusing on a student's ability to self-assess their educational success as it relates to their attitudes and perceptions in engineering. An evaluation of a student's confidence related to engineering states of mind are the focus in this research. This study proposes to contribute to this body of research (increasing retention of engineering students) by developing a tool that uses existing validated assessments to support a student's ability to self-assess their engineering academic career. This tool will serve first- and second-year students. The aims of the study focused on the following:

1. To define a UMBC student's (Third, Fourth and Fifth year) successful Engineering State of Mind. This was essential to the creation of the Engineering State of Mind Instrument (ESMI) giving students indirect peer mentoring opportunities through online profiles.
2. Determine the common themes of Freshman Engineering students Engineering State of Mind and the attitudes and perceptions of the different population groups of the study. Specifically, in gender, ethnic affiliation, and mentorship programs in engineering. (Instrument Efficacy)
3. Determine how first year engineering students' perceptions change after they have gained an understanding of their perceptions and attitudes of engineering. (Intervention Efficacy)

This research paper will concentrate on Aim #2 and #3. Additionally, only the groups of study are discussed. Further population groups will be reviewed in further research papers.

Background

Students in their first and second year of engineering school, although receiving good grades, may struggle with their understanding of whether they are suitable as an engineer and if they will graduate. They may seek help from an advisor, peer, mentor; or do nothing at all.

This study examines the engineering population and how a self-assessing tool can help a student to identify their engineering identity. Currently, at the University of Maryland Baltimore County (UMBC), an average of 45% of students who declared their major to be mechanical engineering graduate from the program in 6 years. Of the graduating population in mechanical engineering, women and men show equal graduation rates of 50% to 60% in five years. Computer Engineering and chemical engineering graduate around 48%-55% [4].

The goal of this research is to create an instant feedback tool that will allow students an opportunity to gauge how they perceive the field engineering as it relates to their academic career. The tool will be developed from validated surveys from research and the Social Cognitive Career theory.

National Best Practices to Retain Students in Their First Year

In 2012, the American Society of Engineering Education (ASEE) produced a report entitled *Going the Distance*, detailing "Best Practices and Strategies for Retaining Engineering, Engineering Technology and Computing Students"[5]. In this report, a literature review and survey were conducted documenting over 60 strategies and best practices in retaining engineering students. These strategies were divided into three categories including "student-focused strategies and practices; faculty-focused strategies and practices; and institutional and departmental-focused strategies and practices" [2]. Common practices mentioned at universities included "tutoring, mentoring, learning centers, programs specifically developed for at-risk students, programs specifically for first-year students, academic advising and career awareness" [5, 6]. These practices are often referred to as High Impact practices [2].

Current Practices at the University

At UMBC, colleges prioritized changing the culture of first year classes from being traditional 'weed' out courses to being retention focused. In the last decade, the university has invested in new initiatives formulated through faculty and staff committees that focused on student success. These committees and initiatives included focus areas around advising & graduation, applied learning, first year experience, academic progression (persistence), student engagement, student wellness and student financial [7].

Additionally, the university has many nationally known scholar programs that have shown to increase student persistence in the STEM fields. This includes the Center for Women in Technology (CWIT), Meyerhoff Scholars program, an Honors College and S-STEM scholars (just in mechanical engineering).

Literature review

Social Cognitive Career Theory: Influences of Career Choices.

As an important foundation of this research the Social Cognitive Career Theory (SCCT) was used as the framework for developing the survey instrument. SCCT proposes that career choice is influenced by the beliefs the individual develops and refines through four major sources: mastery experiences (personal performance accomplishments), vicarious learning, social persuasion, and emotional and physiological states [8, 9].

Mastery Experiences affect "student's perceptions and actual preparation for success in engineering and other STEM fields through their perceptions of their chances of completing their engineering degree, particularly if they appear less prepared than their classmates [10]." These experiences are opportunities to learn and apply strategies learned to perform a task successfully.

If the student performs a task successfully, it is likely this person will not doubt their ability. Social persuasions refer to a student's feelings of efficacy as a result of the encouragement from significant others (i.e, parents, friends, faculty) and vicarious experiences are based on learning through observation from others [10]. "The value of social persuasion and vicarious experiences appear in the engineering literature regarding the importance of social support and role models to success in STEM fields [10]." Social persuasion refers to how others' judgments, feedback, and support either enhances or hurts self-efficacy [11]. " Emotional and physiological states as a source of efficacy expectation are evidenced in the disruptive anxiety associated with phenomena such as stereotype threat [12]." Stereotype threat occurs when an individual is aware of a negative stereotype in a specific environment that exists about a group to which she or he belongs, and the knowledge of this stereotype incites anxiety which can hinder performance [10]. In this research, physiological states, from the Emotional and Physiological classification, are not examined, only emotional constructs.

Retention and Engineering

Literature addressing low retention has traditionally concentrated on student preparation and academic results. "Until the early 1990's, the focus of research on the issue of successfully recruiting and retaining women, and men, in technical fields focused on the students themselves" [13]. Constructs to evaluate the retention success of the engineering student focused on high school preparation and competences in math and science. Faculty and administrative personnel in science and engineering (S&E) undergraduate programs traditionally held the view that students who left engineering were simply not competent, and it was an advantage for all those involved to remove these students from the S&E programs [14]. More recent research shows that "Researchers have demonstrated that although many engineering educators believe high attrition rates among engineering students are evidence that weaker students are being weeded-out, this concept is flawed" [15, 16]. Additional research showed that the grade distribution of students who drop out is similar to those who persist. Instead of GPA, attitudinal differences between minority and majority students were discovered that were related to a student's likelihood of remaining in the program [16, 17] [18]. Further evidence explained that students who left engineering did so because of different perceptions of the institutional culture[10]. This study was confirmed and evident in Tinto [19, 20] as it related to college students in all majors. More specific studies showed that female Science and Engineering undergraduates left engineering for these same reasons [21, 22].

Self-efficacy

As defined by Bandura (1986), self-efficacy "refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments." Bandura claims that self-efficacy determines "the courses of action people choose to pursue, how much effort they put forth in given endeavors, how long they will persevere in the face of obstacles and failures, their resilience to adversity, whether their thought patterns are self-hindering or self-aiding, how much stress and depression they experience in coping with taxing environmental demands, and the level of accomplishments they realize." Current self-efficacy research literature makes a convincing case that a strong sense of self-efficacy is integral to all student's entries and persistence in engineering [11, 23, 24].

Anxiety and its effect on self-efficacy

Anxiety levels of college students continue to be a problem for colleges nationally. "In 2016, nearly two-thirds of college students reported "overwhelming anxiety," up from 50 percent just five years earlier, according to the National College Health Assessment" [25]. "Mental health experts, advocacy groups and public health organizations describe the incidence of anxiety and depression among college students and college-age young adults as an epidemic" [26-28]. This anxiety is also evident in engineering students [29]. However, the source may come from both academic and non-academic demands or internal concerns regarding their future as an engineer. This anxiety can compromise the amount of self-efficacy a student possesses, "manifesting itself as reduced motivation, concentration, or reasoning capability. These symptoms often lead to a loss of confidence in engineering abilities and may reduce commitment to engineering degree programs, resulting in lower retention" [29-33].

Self- Assessment

To better support the above points, an engineering student should have the ability to self-assess their state of mind. A student's ability to self-assess can promote meaningful and authentic learning, intrinsic motivation, internally controlled effort and more [34-38]. It has also been found that by "enhancing one's self-awareness, an individual's performance is directly influenced in a positive direction" [39, 40].

The assessment process involves self-monitoring, self-judgement, and identifying learning targets and making and receiving instructional correctives. The process cycle then begins again with the evaluation of the student's corrections. Self-monitoring involves focusing attention on an aspect of behavior or thinking [41]. Self- Judgment involves identifying standards or criteria that give a student awareness of what they know and what is needed to grow [35]. Rolheiser and Ross (2001) explain, through a literature review of research and practice, that common outcomes showed "Students who are taught self-evaluation skills are more likely to persist on a difficult task, be more confident about their ability, and take greater responsibility for their work" [38]. Instructional correcting involves someone external providing skills or resources to help a student improve or correct misunderstandings. With this step, awareness of options or recommendations needs to be made available.

Rationale for Enhancing Self-Assessment

Studies performed to evaluate self-assessment draw on three theories of learning to justify nurturing this ability in students. These include the cognitive and constructivist theories of learning and motivation, metacognition theory, and self-efficacy theory [34].

The cognitive and constructivist theory of learning and motivation postulates that students learn through discovery. Students learn new material by having access to resources and being guided as they "assimilate new knowledge to old and to modify the old to accommodate the new" [42]. Additionally, students are motivated more intrinsically, rather than receiving external affirmation. This theory requires engagement on the part of the learner [43]. "Without some kind of internal drive on the part of the learner to do so, external rewards and punishments such as grades are unlikely to be sufficient"[42].

Experimental Methods/Materials/Project Approach

Engineering State of Mind Instrument (ESMI)

Interviews conducted in 2011, at the university in the department of xxx, [44] revealed themes that were used to create and develop the survey used in this research. Measuring the identified themes, a survey was developed using components from five different instruments including the Pittsburgh Freshmen Engineering Attitudes Survey (PFEAS) [17], Longitudinal Assessment of engineering self-efficacy (LEASE)[45], Students Leaving Engineering (SLE) [45], Academic Pathways of People Learning Engineering Survey (APPLES) [24], and the Mentoring Functions Questionnaire [46]. Each of these instruments has established validity and the reliability of drawing correct conclusions based on the data attained from their assessment [47]. Validation and reliability were re-evaluated when executing and developing the instrument as a self-assessment tool.

Description of the Five Instruments in the ESMI

The Pittsburgh Freshmen engineering attitudes survey (PFEAS) was developed in 1993 to evaluate the efforts to improve engineering education at the University of Pittsburgh. "The PFEAS was constructed to measure many of Seymour and Hewitt's primary reasons students leave engineering. The PFEAS attitudinal subscales were administered to assess students' attitudes about engineering" [17]). Seven factors identified by the original authors were postulated to underlie the attitudinal items: general impressions, financial influences, contributions to society, perceptions of work, enjoyment of math and science, engineering as exact science, and family influences.

The LAESE (longitudinal assessment of engineering self-efficacy) instrument was used to measure the self-efficacy of women studying engineering, including feelings of inclusion and outcomes expectations[48] [49].

The Academic Pathways of People Learning Engineering Survey (APPLES) instrument is one of the research tools developed and used by the National Science Foundation-funded Academic Pathways Study (APS). The 16 multi-item variables in the instrument were designed to expand the understanding of the undergraduate engineering experience and an undergraduate's transition into the workplace.

The Assessing Women in Engineering (AWE) Students Leaving Engineering (SLE) instrument [10]is a quantitative instrument used to collect data on the reasons engineering students choose to transfer out of engineering. To fully encompass all influences and background of the student, this instrument includes items related to the reasons for initially pursuing engineering, such as high school preparation, intended transfer destination, career plans, participation in extracurricular activities and factors that impacted respondents' decision to leave engineering.

The Mentoring Functions Questionnaire is a 9-item survey developed by Pellegrini and Sandura (2005b) to measure protégé satisfaction with the mentoring relationship in three dimensions: career, psychosocial, and role modeling.

Reliability

Table 1 (Appendix) describes the 17 multi-item Likert scale variables in the instrument created for this study. Variables were chosen that match closely with the themes derived from the qualitative analysis in 2011[44]. To ensure consistency, reliability was re-assessed. These variables demonstrate to impact a students' decision to persist and major in engineering [24]. Included in the table for each variable are the Cronbach's alpha scores (tested using SPSS), a test of internal consistency of the individual items that comprise each variable. These scores measure the statistical reliability resulting from the similarity of individual item responses. The scores also characterize the degree to which the items in a scale can be treated as measurement for the same underlying construct (such as motivation). Cronbach‘s alphas of .60 and higher was considered to be an acceptable level of internal consistency [50]. The Likert scale for each variable can be found in the foot note of the table.

Construction of the Instrument and Website

Starting in the Fall of 2017 through the Spring 2019, the Engineering State of Mind of Instrument was developed. Based on the background knowledge mentioned above, the information helped optimize the platform to create the needed algorithms to develop the instrument. In conjunction with the instrument development, the engineeringed.umbc.edu website was constructed.

To provide the best combination of flexibility and user-friendly output, Qualtrics Survey online software was adopted. This platform allowed the ability to create algorithms that calculated the user's results and provided immediate feedback. Calculation of the 17 variable measures consisted of a summation of the totals for each participant. Item scores were summed, the scales were then normalized and multiplied by 100 for reporting. Method for computing multi-item variable scores was modeled from Sheppard et. al. (2010). The values obtained from Qualtrics was confirmed with Statistical Package for the Social Sciences (SPSS) to ensure consistency.

As a part of the ESMI tool, engineeringed.umbc.edu was developed to help provide convenient and readily accessible platform to understand the results for the participants. Each of the variables, as it relates to the Social Cognitive Career Theory (SCCT) constructs, are explained to the user and detailed scales with recommendations (high impact practices) are provided to assist the user in understanding the meaning behind their score. These recommendations included readily available offerings on campus such as directing students to professional societies, mentoring programs, counseling or adviser help, seeking the career center, and utilizing our academic success offices.

Dissemination of ESMI

Once IRB approval was obtained, data collection was a multi-step process:

1) Dissemination of ESMI to Juniors and Seniors to develop profiles for indirect peer-mentoring. This was an integral part of the development of the ESMI. Results of this is not reported in this paper. An example profile is shown in the appendix.

2) Pre-assessment dissemination of ESMI to Engineering 101 to first-year engineering students (specifics groups of study) at the beginning of the semester.

3) Post-assessment dissemination to Engineering 101 students (all groups of study), at the end of the semester assessing the efficacy of the instrument and interventions.

4) Qualitative Impact Survey follow-up to all groups in Engineering 101.

In this paper, Engineering 101 students, will be the focus of the research. Further reports will include other populations to include a comparative analysis gender, ethnic and program affiliations.

Dissemination of ESMI to Freshman Engineering Students.

To thoroughly assess the instrument, the college's first-year engineering course (with ~270 students) was evaluated. This is a required course and therefore all three engineering disciplines (mechanical, computer, and chemical engineering) are represented. The class delivery format includes one lecture and 10 discussion sections ranging with 20-30 students.

The ESMI was implemented at the very beginning of the semester. To assess the impact, the 10 discussions were divided into 4 experimental groups. Table 2 also explains the dissemination plan shown in the Appendix.

- Group#1: Received ESMI at the start of the semester. No interventions took place. They received ESMI again, toward the end of the semester with follow up questions on the impact of the instrument.
- Group#2: Received ESMI at the start of the semester. Interventions took place. They received ESMI again, toward the end of the semester with follow up questions on the impact of the instrument.
- Group#3: Did not receive ESMI at the beginning of the semester. Did not receive interventions. They received ESMI toward the end of the semester with follow up questions on the impact of the instrument.
- Group#4: Did not received ESMI at the beginning of the semester. Received interventions. Contained organic interventions of Honors College and First Year Experience (FYE) affiliated students. They received ESMI toward the end of the semester with follow up questions on impact of the tool.

Interventions provided in Group #2 included communicating information dedicated to variables related to improving their attitudes, perceptions and self-efficacy. Additionally, third, fourth- and fifth-year students were asked to take the instrument to serve as both an indirect peer-mentor for first year students and comparison variable.

Results and Discussion

Pre-Assessment of Engineering 101(ENES 101); Group #1 and Group #2

To provide a baseline for the study, Group #1 and Group #2 were given the instrument at the beginning of Fall 2019 semester. A total of 169 students participated in the study. Prior to ENES 101, 88.2% of the students who participated in the study came straight from the P12 secondary education environment. Only 7% of the population were from a 2-year college and less than 2% were at a four-year university.

Social Persuasion Vicarious Experiences

First year engineering students revealed at the beginning of the semester their primary motivations to study engineering were based on the Financial Rewards, 72%, Intrinsic Psychological 81%, and Intrinsic Behavioral 81%, and Social Good, 80%. Parent and Mentor influence were the least motivating variables for these students at 18% and 28%, respectively.

Mastery Experiences

At the beginning of the semester, first year engineering student overall valued the essential engineering skills at 82%. However, Math and Science skills were higher, 88%, than the Professional and Interpersonal skills, at 74%.

Emotional States

The participant's overall Emotional States were moderate at 74%, at the beginning of the semester. The students also responded with moderately high feelings about being able to cope with failure (81%), Coping Self-Efficacy, and expecting they can succeed or fit into an engineering career (82%). However, both groups felt unsure if they could relate to people in their class, responding with moderately low feelings of inclusion at 60%. Engineering 101 is typically an engineering student's first class, and possibly first exposure, to engineering. Most of the students in this population, 88.2%, were previously in a secondary education environment, making this their first college experience.

Confidence Group #1 and Group #2

Students were asked to reflect on their confidence in completing their engineering degree at the beginning of their academic career in college and current (present) confidence. At the time of the pre-assessment, most students were just starting their college careers. Therefore, reflection on their beginning confidence, at 80%, would likely project from their high school experiences. This also explains their present confidence in completing their degree reporting at moderately high 77%.

Post-Assessment of Engineering 101(ENES 101); Group #1 -Group #4

First year students in Engineering 101, were given the instrument at the end of the semester. All groups of study, Groups #3 and #4 were included. A total of 177 students participated in this study.

Social Persuasion Vicarious Experiences

Motivations to pursue engineering was fairly consistent between all four groups. Groups #1-#4 primary motivations for becoming an engineer included Social Good at 87%; Intrinsic Behavioral at 85.75%; and Intrinsic Psychological at 85.76%. Financial Rewards was moderate at 73.21%. Mentor Influence at 35.82%, and Parent Influence at 21.0%, were the least motivating variables among the population. Overall motivations, SPVE variable, were moderate at 66.34%, showing most of the population had more than one variable that motivates them to study engineering.

Significant differences were found between the groups on the Intrinsic Psychological variable, experiencing enjoyment that is inherent in the field, χ^2 (3, N=177)=6.886, p <.1, with a small effect size of 2.8%. Group #3 was significantly more motivated by Intrinsic Psychological, at a high 88.95% compared to Group #1 who participated in the instrument at the beginning, at 81.30%, p<.1. By having the instrument in the beginning, Group #1 engineering motivations were more equally valued between Social Good 86.22%, Intrinsic Behavioral 86%, and Intrinsic Psychological. Group#3 had higher value in just two motivations Intrinsic Psychological and Social Good 89%.

Group #2 was significantly more motivated in this variable, 87.66% compared to Group #4 that did not have the instrument at the beginning of the semester, at 79.50%, p<.1. Group#2, like Group#1, showed more consistent motivations between Social Good 88%, Intrinsic Psychological and Behavioral both at 87%, than Group #4, who's highest motivation was Social Good at 87%.

Mastery Experiences

Students were asked their perceived importance of engineering skills as it relates to math and science, as well as professional and interpersonal. Examining the means between the groups, no significant difference was found. However, Group #1 valued the skills of engineer higher than the rest of the groups in all three variables.

Group #2, with interventions and the instrument at the beginning of the semester, valued the math and science skills less than Group #4, with only interventions. However, with the instrument, Group #2's value for each skill set exhibited equivalent importance with math and science at 85.6% and interpersonal and professional skills at 78.22%. Group #4, however, valued Math and Science at 90.96% and Interpersonal and Professional skills at 76.39%.

Emotional States

The engineering 101 post-assessment population was assessed for their engineering Emotional States according to their groups. Group #1 had the highest Coping Self-Efficacy at 84.92% where Group #4 had the least at 79.18%. Group #2 had the highest Engineering Career Success Expectations, 85.05%, but Group #4 had the lowest 81.89%. Group #3 had the lowest Feelings of Inclusion, 66.62%, where Group #4 had the highest at 72.14%. Group #1 and Group #2 had overall better emotional states by having the instrument at the beginning of the semester compared to Group #3 and #4 who did not.

Confidence

Students in all four groups were asked their beginning and present confidence in completing their engineering degree at the end of the Fall 2019 semester. No significant differences were found between the groups on individual variables.

Group #1, in the post-assessment, reflected a significantly higher beginning confidence at 84.37% than there present confidence at 74.31%, $p<.05$. Group #3, had a high (83.73%) beginning confidence at 83.73% and decreased in their present confidence by 2.78%.

Group #2 and #4, also showed no significant differences between beginning and present confidences. Group #2 reflected a moderate beginning confidence of 79.38%, whereas Group #4 felt their confidence was high at 86.31%. Group #4 and #2, felt their confidence was slightly less at the beginning semester, showing only a 4.76% and 3.39% drop.

Pre & Post Comparison Assessment of Engineering 101(ENES 101); Group #1 -Group #2

Group #1 and Group #2 received the ESMI in the beginning and at the end of the semester. However, only Group #2 received interventions. This section will discuss any significant differences from pre-assessment given at the beginning of the semester, and post-assessment given at the end of the semester, in receiving the ESMI.

Pre and Post Social Persuasion and Vicarious Experiences (SPVE)

Group #1

Several increases were found in Group #1 motivations including improving welfare of society (Social Good) that had a pre of 81% and increased to a post of 86.57%, Financial motivation that increased from 74.04% to 76.81%, and Intrinsic Psychological motivation that increased from 83.02% to 87.11%. General Impressions of Engineering decreased from 80.20% at the beginning of the semester to 75.41% at the end of the semester. Although this group did not receive interventions, the instrument helped students be more intentional about self-reflection on various reasons to study engineering.

Group #2

Group #2 showed increases on most motivation variables with significant differences. Interventions combined with the instrument strengthened the student’s motivations in engineering. These increases were shown on the motivation of Financial rewards, which increased from 71.68% to 75.22%, Social Good 79.51% to 87.38%, Mentor Influence 26.63% to 32.67%, Intrinsic Psychological 81.24% to 87.82%, Intrinsic Behavioral 80.85% to 87.65%, and their overall motivation, SPVE, went from 62.17% to 66.81%.

The motivation to pursue engineering for Social Good, revealed a significant difference χ^2 (1, N=144)= 14.093, $p < .05$, with a moderate effect of 5% and in Intrinsic Psychological χ^2 (1, N=144)= 2.775, $p < .1$, with a small effect of 1.9%. Overall motivation to pursue engineering also significantly increased in Group #2, SPVE, χ^2 (1, N=130)=5.256, $p<.01$, with a small effect size of 3.7%.

Group #2 received opportunities such as peer mentorship, visiting upper level classes, class reminders on resources on campus, emails on seminars of companies and research, and simple encouragement throughout the semester on understanding that success isn't just measured in grades.

Pre and Post Mastery Experiences (ME)

Group #1

Group #1's Interpersonal and Professional Skills value significantly increased from 74.66% to 80.12%, χ^2 (1, N=130)= 4.397, $p < .05$ with a small effect size of 3.4% and their overall value of the engineering skill set 81.94% to 85.35%, χ^2 (1, N=130)= 2.994, $p < .1$, with a small effect size of 2.3%.

Group #2

Although no significant difference was found, the Perceived Importance increased slightly from 75.25% to 78.22%. Math and Science decreased from 88.32% to 85.61%, showing that with the interventions and the instrument, the values were now more equal value for each engineering skill set.

Pre and Post Emotional States

Group #1

All emotional variables increased, showing a significant increase in their overall Emotional States from 76.88% to 80.15%, χ^2 (1, N=130)= 3.147, $p < .1$ with a small effect size of 2.4%. Other important increases due to the instrument were shown in feelings of inclusion changing from 65% to 70.98%.

Group #2

Group #2 increased in all Emotional State variables. Having the interventions along with the instrument strengthened the increase showing significant difference on several of the emotional state variables. Feelings of Inclusion increased from 55.81% to 67.39%, χ^2 (1, N=144)= 8.451 $p<.005$, with a moderate effect size of 5.9%. Engineering Career Success Expectations increased 81.24% to 85.05%, χ^2 (1, N=144)= 4.624 $p<.05$ with a small effect of 3.2%. Final significance was also found on the overall engineering Emotional State variable χ^2 (1, N=144)= 6.746, $p < .05$, with a small effect size of 4.7%. increasing from 72.55% to 77.93%.

Confidence

Group #1 pre-beginning confidence of 79.88%, and post-beginning confidence 84.23%, increased from the start of the semester. Student's felt they were more confident in the beginning than originally indicated. However, their Post-Present confidence of 74.41% was perceived less than their Pre-Present confidence of 79.0%.

Group#2 confidences did not change from taking the ESMI at the beginning verses the end of the semester due to having both interventions and the instrument. Their pre-beginning confidence of 80.28%, decreased at the end with the post-beginning at 79.38%, a change of -1.03%. Their post-present confidence (75.99%) also had a minor decrease of -0.6% from the pre-beginning confidence (75.88%). Group #2 lacked a gap in their confidence compared to Group #1 who did not receive interventions.

Qualitative Impact Post- Survey

Students who participated in the post-assessment were asked to take a follow-up impact qualitative survey. Common themes were found and shown to support the pre-defined aims, are highlighted and discussed as they relate to the groups of study. Quotes from the students are provided as examples to support the themes. Although several themes were found, more common responses reflected the following:

- Profiles helped relate to engineers with difficulties – AIM #1
- Value and connection of engineering skills and practices (professional and technical skills) to themselves beyond the classroom – AIM #2
- ESMI – Reflection of attitude, perception and value - AIM #2
- Reinforcement as Engineer (Retention) - AIM #2 & #3
- Expanded understanding of Engineering - AIM #2 & #3

Profiles helped relate to engineers with difficulties – AIM #1

The students from each of the groups valued being able to look at upperclassman peers ESMI scores and what they struggled in their first and second year of college. For example, a female Latin/Hispanic student from Group #4 explained:

...I saw one of the profiles that said someone almost dropped out of their major because of not doing well in one class but ultimately its going to happen. that helped me because I know even if I struggle a lot of other people will be struggling too so I won't be alone

Another example was shown in Group #4 from a female, white American student:

I actually feel a lot better after looking at the profiles, because it makes me realize that the difficulties I am having, such as my struggle with math and time management this semester, are normal...

Value and connection of engineering skills and practices (professional and technical skills) to themselves beyond the classroom – AIM #2

Many of the students mentioned how they learned more about themselves and how they can use engineering outside the classroom environment. An example of this was shown in Group #1 with a Non-Binary, White American student reflected from initially taking the instrument,

…I have decided to become a computer engineer with a minor in theatre. I realized that solely being an engineer would not be beneficial to be because I miss the emotional and creative outlet that theatre provided for me, and that broadening my outlook would provide more opportunities in the engineering field in general, and the technical theatre world more specifically— therefore making engineering more enjoyable to me.

ESMI – Reflection of attitude, perception and value - AIM #2&#3

When reflecting upon the ESMI and what they gained, students mentioned instances related to their attitude, a perception or value had changed. For example, an African American Female in Group #4 explained:

…It was also refreshing to see the question about being able to be okay if you fail a test. You are supposed to take that failure as a learning opportunity and not something to discourage you from your dreams.

Reinforcement as Engineer (Retention) - AIM #2 & #3

Several students also indicated that the instrument and/or interventions help reinforce their choice in continuing in the field in engineering. A female African American Black female form Group #3 stated:

I learned that I like engineering because I like actual engineering and not because engineering offers a lot of money. I like to build things the physical building and a bit of the design process. This affirmed my desire to be a civil engineer or just an engineer in general. I also learned I am more motivated than I previously thought which makes me even more motivated to be an engineer

Expanded understanding of Engineering - AIM #2 & #3

As a first-year student, it's common to find misconceptions with the engineering field. Using the ESMI, participants in the study commonly explained that their understanding of the engineering field was expanded. A Male, Asian American, Non-Programmed in Group #3 explained:

I always expected an engineer's main tasks being do math, build, and design. I never really pictured another part of an engineer's job is to work with their peers and present their findings.

And another instance is shown with a Male, White American Non-Programmed student in Group #1:

There are many roles that come with engineering and you don't have to be good at all of them to be a successful engineer.

Conclusion and Future Work:

From this study, it is evident that a student benefits from understanding their Engineering State of Mind with a connection to high-impact practices [2] shown through the results. Engineering classes, alone, do not nurture the student's ability to think beyond many of the common misconceptions of engineering and how they play a role in the field. Students are intrinsically motivated [1] and offering a way that they can control and receive this output makes them likely to adjust their mindset into meaningful and, hopefully, positive behaviors.

Freshman engineering students are mostly motivated by Intrinsic Psychological, Intrinsic Behavioral and Social Good. Financial Rewards was a high motivated factor for Freshman in the pre-assessment stage of the study. In the post assessment, Financial Rewards was reduced to a moderate motivation. After a semester of being exposed to engineering and exploring the discipline, students may begin to understand better the holistic value of being an engineer.

The motivation to improve welfare of society (Social Good), was a common variable that increased in all groups of study. Over time a student will start to value how engineering ultimately impacts humans and the environment. In Engineering 101, there are entire weeks of class dedicated to discussing engineering careers and the ethics of engineering. Group #2's population significantly increased on this variable by the end of the semester.

Essential skills, such as the interpersonal and professional skill set is a valued and needed component to an engineer as shown in industry and academia [5, 51, 52]. In this study, Math and Science skills were commonly valued higher than Professional and Interpersonal Engineering skills by first year students in this study. Engineering is traditionally classified as being a discipline that requires you to be 'excellent' or 'superior' and 'love' Math and Science [53]. This message is usually provided through various spaces to include the P12 classroom, families and even conventional practicing engineers. This misconception leads to the Professional and Interpersonal skills being devalued as less necessary for the field, especially when students are first entering into engineering. After a semester, an increase was shown on the importance of Professional and Interpersonal skills in all groups. A greater number of significant increases and high change was found in Group #2 compared to Group #1, due to receiving both the instrument and interventions.

Freshman engineering students, in all groups of study, had moderately low to moderately high (high 50's to low 60's) Feelings of Inclusion. However, in the post-assessment of emotional states, all variables in Group #1, who had the instrument both at the beginning and end of the semester, increased compared to Group #3. This increase was only strengthened in Group #2 which had both the instrument at the beginning, and the interventions, compared to Group #4 who lacked the instrument at the beginning.

This research empowers the student to recognize their own needs, providing them a way to self-assess and change their mind set. Throughout higher ed, finding ways to help students succeed is a constant and major initiative. There is often a disconnect where the student isn't aware of how resources are helpful to them, and without that understanding, many initiatives aren't effective. Encouraging students to better understand their motivations will provide insight into what kind of high impact practices to utilize to be successful instead of them grasping at various solutions without a firm understanding of their engineering frame of mind. They will no longer feel like they are being fit into a mold, but instead they will be able to see and articulate their different motivations, feelings and values. In the qualitative assessment, students indicated that they would use the recommendations in the future more than in the present. Having the knowledge that there is something they can turn to, a tool that is there when they want to use it, can provide a comfort and sense of safety to them.

Limitations of Study

Several limitations were identified in this study. In this section, these limitations are addressed. Many of them lend themselves to potential future work.

Variables in each Social Cognitive Career Theory (SCCT) classification were assessed as contributing equally to each construct (Social Persuasion Vicarious Experiences, Mastery Experiences and Emotional States). Further analysis is needed to fully predict these constructs. Evaluating the correlations could lead to better evaluation of each the SCCT constructs.

Several variables had some misunderstandings and misconceptions in their questions. One example of this is Parent Influence. Students may have answered the question in an honest way, feeling it was saying they were forcing them into the major. However, many of our students have parents who are engineers and see them as more of an inspiration. Additional questioning around this variable may help provide a thorough understanding of this influence.

There was clarification needed about the engineering skills. Students felt they valued the skills set but were doing bad in their math or science course. Having additional questions around their confidence in succeeding in math and science may help to better understand the student's mindset as it relates to their performance in classes and the value of engineering skills.

The instrument, although having a question on GPA, did not use academic performance as a contributor to their motivations. Further assessment also could include using GPA as a potential output where higher motivations, feelings and values could result in a higher GPA.

Additionally, Physiological state was removed from the study. Future work could include incorporating questions around feelings of anxiety and physical states of the students. Research has shown, even in Engineering 101, how the students physiological state impacts their ability to succeed in engineering [54].

While Engineering 101 is typically a first semester first time freshman class, it is not homogenous. Around 10% of the Fall 2019 class came from a previous institution (community college or 4-year institution). This population isn't large, but it is possible it could impact the results.

Gender, Ethnicity and Program Affiliation population and variable correlations were assessed and will be reported in future articles.

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Appendix

Table 1: Survey Items and Internal Consistency

1. Motivation: Financial[1] (α=.77) 3 items
Engineers make more money than most other professionals
Engineers are well paid
An engineering degree will guarantee me a job when I graduate
2. Motivation: Parental Influence[1] (α=.80) 2 items
My parents would disapprove if I chose a major other than engineering
My parents want me to be an engineer
3. Motivation: Social Good[1] (α=.75) 3 items
Technology plays an important role in solving society's problems
Engineers have contributed greatly to fixing problems in the world
Engineering skills can be used for the good of society
4. Motivation: Mentor Influence[1] (α=.74) 4 items
A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study Engineering
A non-university affiliated mentor has encouraged and/or inspired me to study engineering
A mentor has introduced me to people and opportunities in engineering
Mentoring Program (Meyerhoff or CWIT) has encouraged and/or inspired me to study
5. Motivation: Intrinsic Psychological[1] (α=.83) 3 items
I feel good when I am doing engineering
I think engineering is fun
I think engineering is interesting
6.Motivation: Intrinsic Behavioral[1] (α=.61) 2 items
I like to build stuff
I like to figure out how things work
7. Perceived Importance of Professional and Interpersonal Skills[2] (α=.79) 6 items
Perceived importance: Self-confidence (social)
Perceived importance: Leadership ability
Perceived importance: Public speaking ability
Perceived importance: Communication skills
Perceived importance: Business ability
Perceived importance: Ability to perform in teams
8. Perceived Importance of Math and Science Skills [2]– 3 items (α=.84)
Perceived importance: Math ability
Perceived importance: Science ability
Perceived importance: Ability to apply math and science principles in solving real world problems

9. Engineering career success expectations[5] – 7 items, (α=.82)

Someone like me can succeed in an engineering career

A degree in engineering will allow me to obtain a well-paying job

I expect to be treated fairly on the job. That is, I expect to be given the same opportunities for pay raises and promotions as my fellow workers if I enter engineering

A degree in engineering will give me the kind of lifestyle I want

I expect to feel "part of the group" on my job if I enter engineering

A degree in engineering will allow me to get a job where I can use my talents and creativity

A degree in engineering will allow me to obtain a job that I like

10. Feeling of inclusion[5] – 4 items, (α=.75)

I can relate to the people around me in my class

I have a lot in common with the other students in my classes

The other students in my classes share my personal interests

I can relate to the people around me in my extra-curricular activities

11. Coping self-efficacy[5]– 6 items, (α=.72)

I can cope with not doing well on a test

I can make friends with people from different backgrounds and/or values

I can cope with friends' disapproval of chosen major

I can cope with being the only person of my race/ethnicity in my class

I can approach a faculty or staff member to get assistance

I can adjust to a new campus environment

12. General Impressions of Engineering[3]– 9 items (α=.81)

I expect that engineering will be a rewarding career

I expect that studying engineering will be rewarding

The advantages of studying engineering outweigh the disadvantages

I don't care for this career

The future benefits of studying engineering are worth the effort

I can think of several other majors that would be more rewarding

I have no desire to change to another major

The rewards of getting an engineering degree are not worth the effort

From what I know, engineering is boring

13. Advisor – 5 items[3] (α=.93)

My advisor takes a personal interest in my career.

My advisor helps me coordinate professional goals.

My advisor has devoted special time and consideration to my career.

I share personal problems with my advisor.

I exchange confidences with my advisor.

14. Mentor- 5 items[3] (α=.93)

My mentor takes a personal interest in my career.

My mentor helps me coordinate professional goals.

My Mentor has devoted special time and consideration to my career.

I share personal problems with my Mentor.
I exchange confidences with my Mentor. (that which is confided; a secret; trust or faith; i.e. a friend does not betray confidences)

15. Peer mentor – 3 items[3] (α=.91)

I share personal problems with my Peer mentor.
I exchange confidences with my Peer mentor. (that which is confided; a secret; trust or faith; i.e. a friend does not betray confidences)
My peer mentor helps me coordinate my academic career goals

16-17. Confidence (leaving engineering)[4] - Independent Variables

When you began your engineering degree, how confident were you that you would complete it?
At the present time, how confident are you that you will complete a engineering degree at this institution?

[1] Four-item scale: 0=Not a reason, 1=Minimal reason, 2=Moderate reason, 3=Major reason

[2] Four-point scale: 0=Not important, 1=Somewhat important, 2=Very important, 3=Crucial

[3] Five-point scale: 0= Strongly Disagree, 1=Disagree, 2=Neutral 3=Agree, 4= Strongly Agree

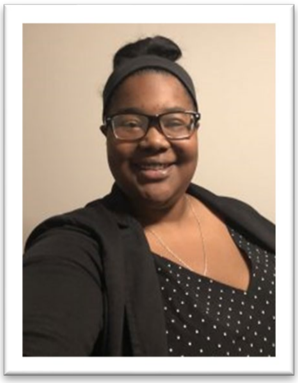
[4] Five-point scale: 0=Not Strongly Confident, 1=Not Confident, 2=Neutral, 3=Confident, 4=Strongly Confident

[5] Six-point scale: 0=Strongly Disagree, 1= Disagree; 2=Slightly Disagree 3=Neither Disagree nor Agree, 4=Slightly Agree, 5=Agree, 6=Strongly Agree

Table 2: Research Model for ENES 101 Discussions.

Timeline: Fall 2019	Group #1 Tuesday 10am, 12pm & 2pm	Group #2 Thursday10am, 12pm, & 2pm	Group#3 Monday 2:30pm & Wednesday 3pm	Group # 4 Tuesday 8am & Thursday 8am
Beginning of September	Receives ESMI	Receives ESMI	No ESMI	No ESMI
September-November	No intervention	Intervention	No Intervention	Intervention
Mid-November	Receives ESMI	Receives ESMI	Receives ESMI	Receives ESMI

Sample Profile for ESMI Website



Name: DeShaunna Scott; Computer Engineering

Email: deshaunnascott@gmail.com

Other Majors/Minors: N/A

On-Campus Affiliations: NSBE, IEEE, National Society of Collegiate Scholars

Internships: Florida International University

On-Campus Research: N/A

Difficulties: I had trouble voicing my opinions. I would tend to take things at face value and not question why they were that way. In turn, I often found myself not fully understanding a subject.

What helped you with these difficulties: Most times when I got frustrated, I would write down all the questions I had about the topic and find my professor to answer them. I would go to office hours or link up with other students taking the same course to work out problems. Most times it helps to think out loud with other people and bounce ideas off of one another. One thing that helped the most was starting group chats with a small number of students in the courses I was taking so that we had a common place to share ideas and sometimes just vent to one another. The biggest key factor that got me through my freshman and sophomore years were student groups. We'd find a whiteboard and work a problem until we could all do it without a problem. It was easier to bring up my confusions and questions in a group of my peers.

Scores:

How do I feel about being an engineer: 59%

Aspects:

- Relating to people in my class or activities: 75%
- Fitting into an engineering career and being treated fairly: 55%
- Dealing with or overcoming problems and difficulties: 47%

How motivated am I to study engineering: 77%

Aspects:

How I value engineering: 92%

I'm motivated to study engineering because of:

- Financial rewards: 78%
- Parental Influence: 0%
- Improvements to the welfare of society: 100%
- Mentor Influence: 67%
- It's own purpose: 100%
- It's practical uses: 100%

How do I Value Necessary Engineering Skills: 78%

Aspects:

- How essential professional and interpersonal skills are: 78%
- How essential math and science skills are: 78%