Why Engineering? – Exploring the Link Between Students' Self-concepts and their Person or Thing Orientation

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***Abstract*— This research full paper examines how a student's self-concept plays a role in choosing to enter an engineering program. Student representation in engineering programs is largely homogenous, which likely hampers growth and progress in this field. Society's views of an engineer and engineering work are similarly homogenous and may lend to the field's lack of diversity. Because the stereotype of engineers is skewed towards "masculine" and "thing-oriented," we measured self-concept in terms of three dimensions: gender, thing orientation, and person orientation. We compared these facets of first-year students to their reasoning for pursuing an undergraduate engineering degree. We found that students' reasons for undertaking an engineering degree aligned with their self-concept, such that role models and their personal views of what engineering entails and accomplishes fit with their self-concept. Understanding what leads students to pursue this challenging degree can help with efforts to reach a more diverse student population and develop the interests of potential engineers from a young age.**

Keywords—engineering students, career choice, self-concept

I. INTRODUCTION

Engineers are vital contributors to the development and wealth of countries [1], especially in our modernized, highly technological world. Recognizing their importance, countries like the United States have invested in growing their STEM and especially engineering workforce [2-4]. Despite such efforts, Americans lag behind both in filling STEM occupational needs of their country and in keeping pace with other countries regarding pursuing education in STEM fields [5-7].

The engineering population in the US suffers from a lack of diverse representation. Female enrollment in undergraduate engineering programs is much lower than that of men [7-9]. Only one fifth of engineering bachelor's degrees went to women in 2005, despite other STEM fields like mathematics, biology, and chemistry having nearly equal representation between men and women [10]. Researchers have identified a trend in which female students interested in STEM fields choose to pursue degrees and careers in non-engineering STEM fields [11, 12].

Consequently, engineering suffers from a lack of diversity that likely holds back its growth and progress. Prior research has shown that relative to homogenous workforces, diverse workforces exhibit more creativity and innovation, which are particularly relevant to engineering tasks (National Academy of Engineering, 2018). Collaboration and teamwork were also found to be enhanced by more equal gender proportions [13]. Such people skills tend to be associated with females, while skills involving things (e.g., technology) tend to be associated with males [14]. Despite people skills often being overlooked, both thing and people skillsets are vital to engineering [15]. If this truth was better known, then perhaps engineering could attract a population that is more diverse and even better suited to the reality of engineering work.

Because self-concept is relevant to career choice, we wanted to see whether students from traditionally unrepresented groups in engineering identified facets of engineering work with which they identified. Two theoretical models commonly used to explain career choices, expectancy-value theory [16] and Social Cognitive Career Theory [17], describe self-concept as a factor in student decisions to pursue a particular career. Given that our population of students has chosen to enroll in engineering, we posited that these students may have resolved elements of themselves that are typically viewed as at odds with an engineer to instead align with engineering work.

In this way, we diverge from other studies of what drives students to pursue engineering careers. Most studies that look at why students go into engineering focus on academic achievement and ability rather than on motivators like personal values and interests [18]. Many of these studies place an emphasis on career *persistence* – staying in the degree originally chosen [19]. Other studies focus on why subgroups of students (e.g., females) tend to drop out of engineering programs at higher rates. In both cases,

focus is shifted to college and academic experiences. In this study, however, we remove focus from detriments to engineering pursuits and focus on what motivates to students to choose engineering in the first place. By uncovering what makes students *want* to pursue engineering, we can better empower educators, parents, and role models to attract more and more diverse talent.

We seek to determine whether the traditionally overlooked groups of engineers of females and people-oriented individuals have different reasons for pursuing engineering than their male, less people-focused, and more thing-focused counterparts. By doing so, we aim to gain a greater understanding of why a greater diversity of students choose to pursue an undergraduate engineering degree to ultimately learn how to better attract these individuals to engineering degrees and careers.

II. Background Literature

A. Perception vs Reality of Engineering Work

As Faulkner illustrates [14], there is "an image of engineering that is at odds with the actual work" (p. 341). Namely, the stereotypical view of engineering is one that is heavily technical and focuses on technology, math, and analytical problem-solving. The reality of engineering work, though, is much more heterogeneous. Engineering work entails a combination of technical expertise and people skills, wherein engineers must engage in tasks pertaining to both technology and interactive tasks ("people) like teamwork, management, and communication. This "technical/social dualism" is what Faulkner refers to as "nuts and bolts and people": masculine thing-focused work ("nuts and bolts") alongside feminine people-focused work.

The social aspect of the job is not insubstantial. Sageev et al [15] surveyed State University at Buffalo graduates who had earned engineering and applied science degrees a few years prior regarding the extent and importance of using communication skills in their jobs. The 208 respondents reported spending an average of 32% of their time working in teams and an average of 64% of their overall work time on some form of communication. Furthermore, long-form responses stressed the importance of this communication time to their success, citing its necessity in career progression. One respondent summed up their evaluation of the importance of communication: "Communications make the difference between success and failure" (p. 689).

Despite the interwovenness of the social element in engineering work, many engineers fail to view it as being part of "real engineering" [14]. Even more problematically, societal norms view the two facets – the technical and the social – as being mutually exclusive. In so doing, people who view themselves as social or as a "people person" are likely to view engineering as at odds with who they are, and perhaps make an engineering degree seem unattainable or undesirable. Instead, they view "real engineering" as "'calculations and drawings' or just 'sums'" [14]. This myopic view likely hinders people who consider themselves to be more people-oriented or female from pursuing engineering careers due to the misalignment.

B. Theoretical Models of Career Choice & Self-Concept

Alignment with self-concept is theorized to be relevant to career choice. Two theories often used to explain students' career choices are expectancy-value theory [16] and Social Cognitive Career Theory [17]. Expectancy-value theory posits that people choose to engage in an activity, such as choosing to pursue an engineering degree, due to a combination of whether they can (expectancy) and want (value) to pursue the activity [19]. A factor of the value of the activity is alignment with one's self-concept: Does performing the activity agree with how the individual views themselves?

SCCT is similar to expectancy-value theory in its application to career choice, suggesting that a combination of self-efficacy beliefs (derived from social cognitive theory) and outcome expectations influence what job a student wishes to pursue. Influencing self-efficacy and outcome expectations are internal factors, including alignment with self-concept (National Academy of Engineering, 2018).

SCCT and expectancy-value theory are particularly useful for explaining why students choose to persist in a given degree; that is, why they stay in that degree after choosing it. However, in this study, we are only concerned with why students select the engineering major. We made this decision because our focus is on how pre-college experiences can shape students, rather than including college factors that play a significant role in persistence (CITE). Thus, we focus on the value component, on which prior empirical work can help inform our study.

C. Theoretical Models of Career Choice & Self-Concept

There are several studies providing empirical evidence of the relationship between values and career choice. Mishkin and colleagues asked 330 undergraduate engineering students what had led them to choose a future engineering career and used the theory of planned behavior (TPB) to examine how choice is contingent upon attitudes, subjective norms, and perceived behavioral control [20]. Their study reveals that undergraduate female students are influenced by the subjective norm factor more than men, meaning women are significantly more influenced than men by other people.

Other scholars found out that there is no difference between males and females with respect to career orientations, however for career intention a significant difference observed between males and females. The majority of the male participants (81%) reported that they intend to pursue an engineering career after graduation and only 59% of female's participants reported that they intend to do so. The results from this study with over 370 undergraduate engineering students suggests that similar initial motivations to study engineering and similar personality between males and females engineering students do not necessarily lead to similar intention to

pursue an engineering career [1]. Carnesciali et al [21] also indicated that gender and socio-economic background influence the timing and selection of engineering majors [21].

A longitudinal study examined undergraduate students' choices in engineering majors, applying Eccles' expectancy-value theory by focusing on subjective task value (STV) construct - the personal importance an individual assigns to engaging in an activity. The study findings suggest that students choose engineering because it is consistent with their personal identity or sense of self [19]. More recent study in South African context used a hermeneutic phenomenology to investigate the factors that influence students career decision-making. The study results reveal that interpersonal, intrapersonal, and career outcomes expectancy (family, personality, and expectations) play influential role in students career choice [22]. In another recent study [23], Tan and colleagues used data from a nationally representative survey to examine engineering students' reasons to choose an engineering major. Their study results claim that student gender is the most important variable predicting engineering major choice, followed by high school math achievement and student beliefs and interests in math and science during high school [23].

Individual differences have also been considered in research investigating factors that influence career choice. Woodcock et al [24] looked at how individual differences in terms of individual's interest to be engage with people or with things in their environment, influences individuals career choices. In their study, the authors used Person and Thing Orientations (PO-TO) scale [25] with data consisting of 7, 450 participants. The major findings of this study suggest that 1) women are more oriented toward people and men more oriented toward things; and 2) PO and TO, for science and engineering college students predicts choice of major and retention.

III. Method

A. Procedure

First-year engineering students were administered a survey during a class period in Fall 2018. All students were asked for demographic information and a measure of person and thing orientations. One third of the students were asked to complete a 5-minute writing exercise on why they have chosen to study engineering. Students completed the survey on Qualtrics survey management system.

B. Participants

Participants were students in a first-year general engineering course at a large land grant university in the southern United States. Of the 533 students, 181 (34.0%) students completed the survey that included the "Why engineering" writing exercise and therefore were eligible for this study. Of those eligible students, 3 (1.7%) did not answer the question or responded that they intend to switch out of the engineering program and thus were screened out. The remaining final sample contained 178 students (N = 178).

In this final sample, 39.1% were female, and 65.3% were White, 21.0% Asian, 2.8% Black, 2.8% Hispanic, and 7.9% from other or mixed racial groups. Additionally, 24.9% indicated that their desired primary major is mechanical engineering, 15.5% computer engineering or computer science, 8.3% civil engineering, 8.3% industrial and systems engineering, and 32.8% other (e.g., aerospace, biological, chemical, electrical, etc.) or general engineering; the remaining participants selected a non-engineering primary major (2.4%) or did not answer (8.3%).

C. Measures

Why Engineering?

Students received the following prompt in the online survey: *This part of this study involves a writing exercise. You will have 5 minutes to* ***write about engineering and why it is important to you and your life****. Please write as if you are writing to your family and close friends about how engineering is important to you and your life and how you decided that you wanted to major in engineering.*

Please use the full 5 minutes to write about the importance of engineering to your life and please try to be as specific and detailed as you can be in your description. You will be moved to the next screen automatically after 5 minutes.

Person and Thing Orientations

We administered Graziano et al.'s (2011) Person-Thing Orientation Scale [25], which taps into the alignment of participants' interests with people and things. Participants took both the Person subscale and Thing subscale, which had reliabilities of α = 0.76 and 0.85, respectively.

IV. Results and Analysis

Results of the focal analysis involving correlations between self-concept and reasons for pursuing engineering are presented in TABLE I.

TABLE I RESULTS OF THE FOCAL ANALYSIS INVOLVING CORRELATIONS BETWEEN SELF-CONCEPT AND REASONS

	sex	PO score	TO score	Egrlmp8	Egrlmp3e	Egrlmp3f	Egrlmp3g	Egrlmp3h	Egrlmp3	Egrlmp7a	Egrlmp7b	Egrlmp7ab	Egrlmp7c	Egrlmp7	Egrlmp5a	Egrlmp5b	Egrlmp5d
POscore	.136																
TOscore	-.051	.146															
Egrlmp8	.236**	.107	-.095														
Egrlmp3e	.234**	.083	.084	.099													
Egrlmp3f	.070	-.010	-.069	.107	.485**												

Egrlmp 3g	-.061	.016	.125	-.017	-.014	-.024											
Egrlmp 3h	-.061	.016	.125	-.017	-.014	-.024	1.000**										
Egrlmp 3	.154*	-.008	-.103	.144	.378**	.635**	.152*	.152*									
Egrlmp 7a	.088	.044	-.077	-.016	-.074	-.067	-.030	-.030	.053								
Egrlmp 7b	.162*	.203**	-.155*	.091	.027	-.014	-.046	-.046	-.110	.057							
Egrlmp 7ab	.167*	.206**	-.198	.041	-.010	-.031	-.056	-.056	-.017	.527**	.811*						
Egrlmp 7c	.134	.185	-.227*	.062	-.013	-.021	-.080	-.080	-.048	.105	.517**	.466**					
Egrlmp 7	.115	.217**	-.240**	.036	-.034	-.017	-.090	-.090	.010	.329**	.507**	.625**	.892**				
Egrlmp 5a	-.007	-.008	.284**	.043	.106	.088	.129	.129	.070	-.003	-.150*	-.113	-.182	-.172*			
Egrlmp 5b	.062	-.063	.159*	.047	.017	-.051	.082	.082	-.083	.069	.055	.115	.108	.143	.247**		
Egrlmp 5d	-.144	-.177*	.012	-.066	.055	.174*	-.056	-.056	.071	.081	-.165*	-.098	-.027	-.018	.103	.091	
Egrlmp 5	-.006	-.107	.176*	-.004	-.003	.051	0.52	.052	-.018	.064	-.064	-.004	-.025	.005	.4004**	.635**	.521**

***. Correlation us significant at the 0.01 level (2-tailed)*
**. Correlation is significant at the 0.05 level (2-tailed)*

code guide – essay response mentioned:

- egrImp8 = gender with respect to self
- egrImp3e = female family member
- egrImp3f = male family member
- egrImp3g = female role model (not family) – I'll probably need to cut because too few
- egrImp3h = male role model (not family) – I'll probably need to cut because too few
- egrImp3 = role model (any gender, relation)
- egrImp7a = people on the job (teamwork, etc.)
- egrImp7b = to help people
- egrImp7ab = to help or work with people (i.e., either 7a or 7b)
- egrImp7c = to help society
- egrImp7 = either 7a,b, or c
- egrImp5a = explaining things
- egrImp5b = making things
- egrImp5d = specific technology or products
- egrImp5 = either 5a, 5b, or 5d

To code the "Why engineering" essays according to alignment with self-concept along male/female and person/thing dimensions, we initially coded mentions of gender, people, and things. After this initial pass through the data, we coded subfactors post-hoc based on identified trends regarding the context with which these mentions occurred. Regarding gender, we found that students often mentioned gender with respect to themselves and to a familial role model. Regarding people, we found that students spoke of people with respect to the nature of engineering work itself (e.g., teamwork, collaboration, leading, communicating, teaching) and to the goals of engineering work – whether to help people or to help society more generally, which we coded separately. If a student mentioned helping people, others, subpopulations, or particular individuals, then this was coded as helping people. If the student did not mention people specifically but rather in larger, general terms such as helping or changing society, the world, quality of life, or making a difference, then this was coded as helping society. Regarding things, we separately coded mentions of explaining things (e.g. taking things apart, exploring how things work), making things (e.g., building, designing, inventing, working with hands), and specific technology or products (e.g., cars, computers, robots, bridges).

A graduate student coded the studies as containing/not containing mentions of each feature. We coded each response as containing or not containing each dimension and subdimension, and single responses could be associated with multiple codes. If a student wrote that a certain (sub)dimension was *not* relevant to their decision (e.g., I didn't choose engineering because I like technology), then we did not mark the corresponding code. See TABLE I for the list of codes, along with their definitions and examples.

For descriptive purposes, we performed frequency analyses among the corresponding dummy variables to examine the prevalence with which first-year students found the aforementioned features important to choosing engineering.

To examine our research question of whether students respond according to their self-concept, we computed bivariate correlations between the codes and each of the three characteristics of interest – gender, person orientation, and thing orientation – to explore how these individual differences associate with reasons to pursue engineering. For comparisons between gender and the codes, we used the phi statistic, which compares two dichotomous variables. For comparison between person and thing orientation and the codes, we used the point-biserial correlation, which compares a continuous variable to a dichotomous variable. We used SPSS version 21 for all analyses.

V. Discussion

The most common reasons for students to choose pursuing the engineering profession are listed below, starting with the two top reasons students being influenced by family member and passion for engineering, following by gaining knowledge and financial standing, with the typical making things and problem-solving at the bottom of the list, and ending with helping people. Reasons to engage with engineering for the female participants not found within the male participants responses were that females were inspired by extracurriculars and family role model. They also mentioned looking forward to teamwork.

Considering the thing-orientation construct, the student's self-concepts were most aligned with reasons such as being inspired by home activities not family, following their own passion and looking forward to making and explaining things rather than engaging with people.

The person-orientation construct was aligned with the least mention above common reason to pursue the profession - helping people.

Students did appear to find ways to find themselves within engineering, especially those whose identities are at odds with the stereotypical view of an engineer. This is especially clear in the case of gender, which is likely more relevant to self-concept than person versus thing orientation. Males did not mention gender (with one exception: a participant saying "When I was a boy"). Because their gender aligned with engineer expectations, they likely did not feel a need to do so (Faulkner [14] explains this way better). Females, on the other hand, often brought up their being female. Females particularly benefit from female role models in the family. More females can become involved in engineering through extracurricular activities and school clubs (we learned about this finding via a supplemental analysis not reported in the paper yet).

Person-oriented students appear to recognize the interactive, people-relevant facets of the job. Given that this group of students is self-selected in that they have chosen the engineering degree, this might differentiate them from other people-oriented students who did not recognize this. They also appreciate the opportunity that engineering presents to help other people and society.

Thing-oriented students showed more intrinsic motivation for pursuing engineering, like general interest in engineering, pursuing engineering-related activities at home, and wanting to work in engineering for what the job is stereotypically known for – working with things. They showed a particular lack of influence from others, likely due to their passion for engineering-related activities.

VI. Conclusions

This exploratory study adds to the body of literature on engineering identity and how it is formed and contributes to college major (engineering or not). We compared two constructs, thing orientation and person orientation of first-year students to their reasoning for pursuing an engineering major. We found that students' reasons for undertaking an engineering degree aligned with their self-concept, such that role models and their personal views of what engineering entails and accomplishes fit with their self-concept.

The next step of the research is to utilize the results from the survey to refine the larger mixed-methods study by looking if there are any differences regarding students' intended engineering major, and the full demographics data (race, 1st generation students, etc.). We then plan to further add to the discussion in engineering education on the disconnect between stereotypes of engineers and the reality of the profession in terms of ABET and NAE and their emphasis on person-oriented topics and the NAE Grand Challenges.

Understanding students' motivation to pursue engineering degree can help with efforts to reach a more diverse student population and develop the motivation of potential engineers from a young age.

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