Investigating the Intersection of Career Aspirations and Engineering Beliefs in First Year Engineering Students

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***Abstract*— This research-category full paper investigates the relationship between first-year engineering students' career aspirations and attitudes towards engineering. Career aspirations describe students' beliefs about professional roles they might perform in the future. Attitudes towards engineering were measured using engineering identity, belongingness within engineering, and specific motivation constructs. Examining the intersection of aspirations and attitudes allows educators to understand how students' intended career choices are related to their perceptions of their educational experience. Using survey data from 2,916 students at four large public universities, we found that an interest in industry-based careers was associated with high engineering identity, belongingness, and motivation scores. We found that gender had a moderate effect on aspirations and attitudes. Additionally, we found that an interest in mechanical engineering was associated with increased certainty in an engineering/industry career, while interests in biomedical engineering, non-engineering STM majors, and non-STEM majors were associated with decreased certainty in an engineering/industry career. These results have implications for the current discourse around how engineering students make decisions about their future careers.**

Keywords—careers, identity, belonging, motivation

I. INTRODUCTION

Science Foundation.The act of educating engineering students is often described as a process of developing professional engineers [1], [2]. In this study, we investigated this potential professionalization by testing the relationship between career aspirations and factors such as attitudes, gender, and major. We define career aspirations as students' beliefs about professional roles they might perform in the future. This investigation into how students develop career aspirations is crucial in light of dominant narratives that prioritize roles in industry that carry the title of "engineer" for engineering graduates. For example, curricular reform within engineering has often leveraged the opinions of industrial employers to determine the skills that engineering graduates need for their future careers [1]–[3]. Messages around the need for teaming and communication skills are often justified by the expectations of working in engineering roles [4], [5]. Additionally, studies about the identity development of engineers often investigate the growth of professional identities and the creation of future engineers [6], [7]. These narratives promote messages that engineering graduates should enter the engineering profession, especially within the industry sector, after graduation.

However, several studies have found that many science and engineering students do not enter the engineering workforce [8]–[11], and even fewer graduates remain in engineering positions. A 2014 U. S. Census report found that "only 26 percent of science and engineering majors are currently employed in a STEM occupation" [10]. Studies focusing on engineers demonstrate similar findings. The Science and Engineering Indicators 2018 Report found that of individuals whose highest degree was in engineering, 42% were employed in a non-engineering role [11]. These findings are not necessarily negative. The Science and Engineering Indicators 2018 Report also found that 90% of these individuals saw their jobs involving some sort of engineering tasks [11]. There remains, however, a discrepancy between the engineering cultural narrative that most graduates matriculate into engineering/industry careers and the actual trends of

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matriculation. This discrepancy necessitates study into how engineering students make decisions about their occupational futures.

This study investigated how the variety of career options available to engineering students might be associated with attitudes that the students have about engineering. We examined student attitudes and beliefs through the constructs of engineering identity, belongingness in engineering, and time-oriented motivation. Engineering identity is a developing area of engineering education research [12], with many interpretations as to what it means to identify as an engineer. In this study, we characterize engineering identity as the extent to which students see themselves as the kind of people that can do engineering and are recognized as engineers. We also investigated students' perceptions of belongingness within engineering, which include their sense of community and their general perceptions of how they fit within the field of engineering. Both belongingness and identity describe aspects of students' attitudes about themselves and their perceptions of the larger engineering community. Finally, motivation constructs were used to understand the extent to which students draw connections between their goals and their engineering courses [13]. The constructs of perceived instrumentality and perceptions of future were drawn from Future Time Perspective theory [14] and have been previously used to study engineering student motivation [15]–[17]. Perceived instrumentality describes the utility the students associate with their first year engineering coursework, while perceptions of future describes the extent to which students have a positive attitude towards their future in engineering [14], [18]. For clarity, these constructs will be subsequently referred to as "attitudes," although we recognize that the term might not fully reflect the nature of students' experiences.

In addition to the attitudes that students develop about engineering, we acknowledge that certain markers, such as gender and interest in engineering majors, might be associated with how students develop beliefs about their future careers. Including gender and majors into our analysis allows us to develop a fuller understanding of the students' experiences and aspirations. Researchers have devoted significant attention towards understanding the experiences of women in the engineering workplace. Women are both less likely to enter the engineering workforce and more likely to leave after being in the workforce [7], [19], [20]. The choice of major within engineering may play a significant role in how students conceptualize their future careers. Studies have shown that students within different engineering degree programs vary with respect to motivation [21], [22], retention [23] and career outcome expectations, such as making money, working with others, and inventing/designing new things [22], [24].

We investigated how first-year engineering students describe their career aspirations and their beliefs about their engineering identity, their belongingness in engineering, and their time-oriented motivations to pursue an engineering degree. Given the discussions about the role that gender and major have on career and attitude outcomes, we included these demographics within the analysis as well. The research questions are:

1) How are the career aspirations of first-year engineering students related to the engineering-specific attitudes these students possess?

2) What is the role of students' gender identity and interest in specific majors with respect to career aspirations?

II. Methods

The data in this study come from of survey responses of 2,916 students attending four large, public universities that are geographically distributed across the United States. Students were surveyed during their first-year engineering course within the first two weeks of the Fall 2015 semester. Thus, these data represent the attitudes and beliefs that first-year engineering students bring with them to their institutions. A detailed description of data collection procedures has been previously described [25].

A. Survey Instrument

The survey instrument contained items relating to students' attitudes, perceptions, beliefs, and goals related to engineering. The analysis for this study was based on student responses to their interest in certain majors, the likelihood they would enter certain career fields, and several constructs related to their identification, belongingness, and motivation towards engineering. Items were measured on a 7-point anchored numeric scale.

The major interest item listed the sixteen engineering majors available across the four institutions, as well as "other STEM major" and "other non-STEM" major. Major interest items were anchored by 0 = "not at all interested" and 6 = "extremely interested." The career likelihood item gave nine career options for students to rate, anchored by 0 = "not at all likely" and 6 = "extremely likely." As written, the items were: Academia (Higher Education), Engineering (Industry), Entrepreneurship/Start a Company, Government/Policy, K-12 Education, Law, Medicine/Health, Non-profit/NGO, and Other.

The items used to measure engineering identity, belongingness, and motivation are displayed in Table 1. Items were measured with 0 = "strongly disagree" and 6 = "strongly agree." The motivation items measured the constructs of perceived instrumentality and perceptions of future. These constructs come from Future Time Perspective theory [26] and previous work in engineering education . These items were selected because of their relevance to our research questions. Perceived instrumentality describes students' perceived utility of specific academic tasks in the present, while perceptions of future describes the extent to which students have a positive outlook on their long-term goals [14], [18]. Items relating to each construct were averaged for this analysis.

Students' gender identities were collected through a measure that allowed students to select more than one option, with the options purposefully ordered to disrupt the typical presentation of "male" and "female." In order, the options were "female", "transgender," "male," "cisgender," "genderqueer," "a gender not listed," and "agender" [27]. This analysis sought to compare the experience of the dominant group, males, to all other students. Students who selected "male" (even if they

Table 1—Attitude constructs and questions, as presented in the survey

Construct	Questions
Identity	I see myself as an engineering
Belongingness	I feel comfortable in engineering I feel I belong in engineering I enjoy being in engineering
Perceived Instrumentality	I will use the information I learn in my engineering course in other classes I will take in the future. I will use the information I learn in this engineering course in the future. What I learn in my engineering course will be important for my future occupational success.
Perceptions of Future	I am confident about my choice of major. Engineering is the most rewarding future career I can imagine for myself. My interest in an engineering major outweighs any disadvantages I can think of. I want to be an engineer.

selected any additional gender identities) were coded as a "1" while all other individuals were coded as a "0." Thus, it is important to note for this analysis that our gender categories are "male" and "not male," rather than the traditional "male" and "female" dichotomy.

B. Analysis

We conducted multiple regression analyses using the R Statistical Software version 3.3.3 [28] and the packages "psych" [29] and "lm.beta" [30]. Only complete responses on the items of interest were used in this analysis, limiting the number of analyzed respondents to 2,583. Because of the multiple tests used in this analysis, the threshold of significance was set to $\alpha = 0.01$ to reduce the risk of Type I error.

To understand the role of interest in particular engineering majors, a measure of certainty in an engineering career was created. This new variable was calculated by subtracting the maximum value for all other career field from the value of students' responses to the likelihood of choosing Engineering (Industry) careers. For example, if student reported that Engineering (Industry) was a "6" while all other options were scored as "0," then that student would receive a "+6" in the certainty variable. A student who indicated that an engineering career was equally likely as another career would receive a "0" in the certainty variable. This variable allows us to calculate the direction and magnitude of students' interest in various career fields, in reference to a "traditional" engineering career

C. Assumption Checking

We examined several assumptions to ensure the quality and validity of our analysis. We used Cronbach's alpha to examine the internal consistency of the latent attitudinal constructs used in our previous work [25], which ranged from .74 to .89, indicating sufficient reliability [31]. Skewness and kurtosis were used for estimates of univariate normality for the artificial measure of certainty and the attitude constructs. We accepted values as not severely non-normal if the skewness was within the absolute value of less than 2.0 and kurtosis absolute value of less than 7.0 [32], [33]. Skewness ranged from 0.0 to -1.6, while kurtosis ranged from 3.4 to 6.6. These measures reflected that all variables could be estimated as reasonably normal. Q-Q plots were also used to examine normality; all items used in the analysis showed normal distributions on these plots. Additionally, ordinary least squares regression is relatively robust to departures from normality [34]. Measures of variance inflation factor (VIF) and tolerance (the reciprocal of VIF) were used to test multicollinearity for each predictive variable used in this analysis. The upper limit of VIF was set at 5 and the lower limit of tolerance was set at 0.2 [35]. The VIF values of all regression models ranged from 1.07 to 1.96, and the tolerance values ranged from 0.93 to 0.51.

III. Results

In this paper, we focused on two research questions: How are the career aspirations of first-year engineering students related to the engineering-specific attitudes these students possess? and What is the role of students' gender identity and interest in specific majors, with respect to career aspirations? To answer these questions, we used multivariate linear regression to investigate (1) the relationship between career aspirations and engineering attitudes, (2) the interaction gender might have on this relationship, and (3) the relationship between major interest and certainty of choice in an industry career. A discussion of the breadth of responses is included prior to these analyses.

A. Description of Career Interests

Engineering/industry careers were the most popular career aspiration, with 81.7% of students reporting a 5 or 6 on a 0 to 6 anchored numeric scale. Entrepreneurship was the next most popular aspiration; 33.1% of students reported a 5 or higher. About half of students reported having multiple career options; 49.4% of students scored two or more career fields at five or higher.

There was a wide variety of responses when considering the careers that students individually ranked as most likely across all nine career fields. Of the 2,583 complete student responses, 2,119 (82%) students indicated that an engineering/industry career was one of their most likely career fields. However, of those 2,119 students, there were 920 (36% of total population) students who answered that both an engineering/industry career and a non-industry career were

Table 2—Significant predictor variables when regressing engineering-specific attitudes on career aspirations

Engineering-specific attitudes	Career Aspirations	Sig.	β	Adjusted R^2
Identity	Engineering	***	.39	0.191
	Entrepreneurship	***	.12	
	Other	**	-.06	
Belongingness	Academia	***	.08	0.165
	Engineering	***	.35	
	Entrepreneurship	***	.09	
	K-12	***	-.08	
	Law	***	-.09	
Perceived Instrumentality	Engineering	***	.34	0.126
	Law	**	-.07	
Perceptions of Future	Engineering	***	.46	0.267
	Entrepreneurship	***	.02	
	K-12	***	-.08	
	Law	***	-.08	
	Other	***	-.07	

Note: Significance indicated as *** for $p < .001$, ** for $p < 0.01$

equally most likely. When given a chance to rate multiple career fields, many students saw more than one viable career option.

B. Attitudes and Aspirations

We created four regression models in which each of the investigated engineering attitudes (identity, belongingness, perceived instrumentality, and perceptions of future) were predicted by the nine potential career fields (academia, engineering/industry, entrepreneurship, government, K-12 education, law, medicine, non-profit, and other). This approach allowed us to compare the relative effect of each career aspiration among all students. The statistically significant results of these models are displayed in Table 2. We found that, for all attitude constructs, indicating higher likelihood in pursuing engineering/industry careers was associated with significantly higher attitude scores. An increase in the rating of likelihood of an engineering/industry careers was associated with an increase in engineering identity ($\beta = .39$, $p < .001$), belongingness ($\beta = .35$, $p < .001$), perceived instrumentality ($\beta = .34$, $p < .001$), and perceptions of future ($\beta = .46$, $p < .001$).

We found that other potential career aspirations exhibited some influence on attitudes. Entrepreneurship was also found to be positively associated with identity ($\beta = .12$, $p < .001$), belongingness ($\beta = .09$, $p < .001$), and perceptions of future ($\beta = .02$, $p < .001$). Law career aspirations, on the other hand, were negatively associated with belongingness ($\beta = -.09$, $p < .001$), perceived instrumentality ($\beta = -.07$, $p < .01$), and perceptions of future ($\beta = -.08$, $p < .001$). Careers in K-12 education were negative predictors of belongingness ($\beta = -.08$, $p < .001$) and perceptions of future ($\beta = -.08$, $p < .001$). Aspirations for careers not listed were also found to be negatively associated with identity ($\beta = -.06$, $p < .01$) and perceptions of future ($\beta = -.07$, $p < .001$). Finally, careers in academia were positively associated with belongingness ($\beta = .08$, $p < .001$). All other career fields were non-significant in the models.

Table 3—Regression models predicting engineering attitudes from engineering/industry career aspirations, gender, and the interaction of aspirations and gender.

Engineering-specific attitudes	Career aspirations, gender, and interaction	Sig.	β	Adjusted R^2
Identity	Engineering	***	.46	0.174
	Male		.15	
	Engineering x Male		-.15	
Belongingness	Engineering	***	.37	0.161
	Male		.14	
	Engineering x Male		.01	
Perceived Instrumentality	Engineering	***	.26	0.128
	Male	***	-.38	
	Engineering x Male	**	.34	
Perceptions of Future	Engineering	***	.52	0.244
	Male		.14	
	Engineering x Male		.10	

Note: Significance indicated as *** for $p < .001$, ** for $p < 0.01$

The proportion of variance accounted for from these models ranged from 13% to 27%. The adjusted R-squared values indicate small to moderate relationships [36]. These results indicate that career aspirations can carry moderate but significant explanatory power in describing engineering-specific attitudes.

C. Attitudes, Aspirations, and Gender

To also examine the association between gender and career aspirations and attitudes, we regressed each of the four attitude constructs on the likelihood values for engineering/industry careers, male identity, and an interaction term capturing the relationship between aspiration and gender. This analysis was performed in order to answer the second research question posed in this study. The choice to only examine male identity and aspirations for engineering/industry careers was made because of the sizable research focus on the connection between gender and careers in the engineering profession [7], [20]. Male-identification was selected to understand the relationship between attitudes and aspirations based on whether or not students were members of the majority group.

The results of the four multiple regression analyses can be found in Table 3. As a reminder, gender for the purposes of this analysis was described through a binary variable that

distinguished students who identified as "male" (majority) from all other students. At the alpha less than 0.01 level, identifying as a male was found to be a statistically significant negative predictor of perceived instrumentality (β = -.38, p < .01). Based on this result we interpret that male-identified students tend to have a lower perceived instrumentality than other students with the same level of career interest in engineering/industry, though this effect is complicated by the interaction effect we found. The interaction effect was identified between gender and aspirations in engineering/industry careers when predicting perceived instrumentality. This interaction revealed that higher interest in entering engineering/industry careers mitigates but does not completely overcome the extent to which males have lower perceived instrumentality of academic tasks in their first-year engineering course. In other words, when engineering/industry career aspirations are low, male respondents were below non-male respondents with respect to perceived instrumentality. However, at high levels of engineering/industry aspirations, these two groups were indistinguishable.

D. Certainty of Career Aspirations and Interest in Majors

Finally, students' interest in engineering majors was studied as a predictor of their relative certainty of entering an engineering/industry career. This certainty was measured by creating a variable that accounted for the strength of likelihood of entering an industry career, relative to all other career fields. Positive numbers indicate greater certainty of engineering/industry over all other fields, while negative numbers indicate that another field was rated more likely than engineering/industry. On a scale from -6 to +6, the mean response was 0.5 and the standard deviation 1.5. Of the 2,583 students included in the analysis, 233 students (9%) had certainty scores equal or above absolute values of three.

When we regressed this certainty variable on 18 majors, we found that all but four were non-significantly related. A summary of results for the significant majors can be found in Table 4. We found that interest in majoring in mechanical engineering was significantly positively associated with certainty about an industry career (β = .093, p < .001). In unstandardized units, for a one-unit increase in interest in majoring in mechanical engineering, on average the artificial measure of certainty increased by 0.08. On the other hand, interest in majoring in biomedical engineering (β = -.18, p < .001), a non-engineering STM major (β = -.07, p < .01), or a non-STEM major (β = -.11, p < .001) was significantly negatively associated with certainty about engineering industry.

Table 4—Significant results from regressing engineering career certainty on interest in undergraduate engineering majors

Significant Predictors (Majors)	Sig.	β	Adjusted R^2
Biomedical Engineering	***	-.18	0.083
Mechanical Engineering	***	.09	
Non-engineering STM Majors	**	-.07	
Non-STEM Majors	***	-.11	

Note: Significance indicated as *** for p < .001, ** for p < 0.01

IV. Discussion

When examining student responses about their likelihood of entering nine different career fields, we found a breadth of career aspirations. While a majority of students indicated that engineering/industry was a highly likely career, almost half of students reported that another career was also highly likely. Since the data were drawn from first-year engineering students, it is perhaps unsurprising that many students are considering multiple career options.

With this understanding of the breadth of career options in mind, we found that career aspirations in industry were significantly associated with specific attitudes towards engineering and interest in certain engineering majors. When regressing the attitude constructs of identity, belongingness, perceived instrumentality, and perceptions of future on students' aspirations to enter various career fields, we found that rating engineering/industry careers as highly likely was associated with stronger positive scores on these measures. Students more readily saw themselves as engineers, felt they belonged in engineering, saw their engineering course work as useful, and had a positive outlook on their future in engineering. Similar results were seen for entrepreneurial career aspirations. Aspirations to enter academia was positively related to belongingness, but were not significantly associated with engineering identity, perceived instrumentality, and perceptions of future.

On the other hand, rating law, K-12 education, and other careers as highly likely was associated with more negative scores on identity, belongingness, perceived instrumentality, and perceptions of future. Students with aspirations in these fields may be unable to see how an engineering undergraduate degree will help them realize their future career goals. The other careers included in this study–medicine, government, and not-for-profit work—were not significantly related to identity, belongingness, perceived instrumentality, and perceptions of future. The proportions of variance accounted for in each of the attitude constructs was small to moderate [36], indicating that there are many factors at play in shaping these attitudes, beyond career aspirations as first-year engineering students.

When we included students' gender identification into the model predicting engineering attitudes from engineering/industry career aspirations, we found that identifying as male was associated with decreased perceived instrumentality. This result indicates that males perceive less utility in their engineering coursework. In other words, male students were less likely to see how their engineering classes would be useful in the future. We also found an interaction between gender and career aspirations, where increased

aspirations to pursue engineering/industry careers mitigated some of the negative relationship between identifying as male and perceived instrumentality. These results may be artifacts of a gender filter, in which a requisite of being a woman in engineering is to be high achieving and strongly motivated [37]. Men, on the other hand, do not necessarily need to see the utility of their courses to enter and remain in engineering [37]. However, the lack of other significant results in terms of gender identification stand in slight contrast to the wealth of literature that indicate that gender is an important factor in students' how students make decisions about future careers [20], [38], their identity [39], their belongingness [40], [41], and their motivation [42].

When we investigated how first-year engineering students rate interest in a range of majors, we found several differences with respect to the certainty these students expressed towards industry and non-industry careers. Interest in mechanical engineering was associated with greater certainty towards engineering/industry careers, while interest in biomedical engineering and non-engineering majors was associated with either less certainty towards industry or more certainty towards non-industry careers. The difference between mechanical engineering and biomedical engineering underscores the importance of understanding the cultures and narratives within engineering disciplines [22]. Gilmartin and colleagues [43] found similar differences between biomedical and mechanical engineering majors and attributed these differences to biomedical engineering students being more likely to use their degree as a bridge to other careers. Finally, the association between interest in STM/non-STEM majors and lack of certainty towards industry careers may be an artifact of students who are uncertain about their future in both engineering degree programs as well as engineering professions.

V. Limitations and Future Work

As this analysis was generated based on survey data from first-year engineering students within their first two weeks of classes, conclusions cannot necessarily be drawn about the role of engineering career narratives on all students' career aspirations. Students may be entering their engineering programs with pre-conceived notions about engineering that may or may not align with existing cultural norms, and that shift over the course of their engineering education. Additionally, the method of measuring students' interest in various careers is limited by the terms used to describe the fields. The survey did not allow students to distinguish between roles in the industry sector and roles in a more general business field that do and do not directly involve engineering. The labeling of industry careers as engineering work may have also biased some students to rate this career field as being more likely. As this data was collected early in their student careers, some respondents may not have known what is meant by and "industry" career. Finally, these data were collected at a single point in time and do not capture the full process of how students make decisions about engineering and their future careers. The correlational, cross-sectional nature of the study does not allow us to establish causality.

Future work involves longitudinal interviews and a second survey of these students later in their student careers. The interviews will follow participants through their time as engineering students, seeking to understand their trajectories, attitudes about engineering, and goals for the future. The follow-up survey poses similar questions about their career aspirations and attitudes towards engineering. This longitudinal analysis will help advance our understanding of how students' career goals are shaped over time in their engineering programs. The survey will also contain a free-response section to give students more flexibility in describing how and why they are aspiring to certain careers.

VI. Conclusions

In conclusion, we found significant associations between students' attitudes towards engineering (their identity, their belongingness, and their motivation) and their aspirations to certain career fields. Students who saw engineering/industry as a likely career path had more positive attitudes towards engineering, aligning with narratives that identify certain careers as expected for engineering students. Identifying as a male was associated with lower levels of perceived instrumentality of their present course work, although aspirations to enter engineering/industry careers had a slight mitigating effect. Interest in mechanical engineering was associated with greater certainty towards an engineering/industry career, while interest in biomedical engineering was associated with less certainty, indicating a need to understand how different engineering disciplines discuss expected future careers. These results have implications for understanding how engineering students make sense of their futures.

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