Impact-Driven Engineering Students: Contributing Behavioral Correlates

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Abstract

Engineering has a long history of developing solutions to meet societal needs, and humanity currently faces many and varied societal challenges. Who are the engineering students motivated to address such challenges? This study explores a sample of 5,819 undergraduate engineering students from a survey administered in 2015 to a nationally representative set of twenty-seven U.S. engineering schools. The survey was developed to study the background, learning experiences, academic activities and proximal influences that motivate an engineering undergraduate student to pursue innovative work post-graduation. As part of this survey students indicated their interest in pursuing work that addresses societal challenges. A step-wise regression analysis is used to predict interest in societal impact and by contrast interest in financial potential with respect to 71 demographic, background and academic experience variables. The results confirm previous studies – a large majority of engineering undergraduates are interested in impact-driven work with an over-representation of female and under-represented minority students.

This study sheds new light on the background and academic experiences that predict interest in impact-driven as compared to financially-driven engineering work. It is found that experiences promoting a service ethic and broadening oneself outside of engineering are important predictors of interest in impact-driven work. What is less expected is the significant importance of innovation interests and innovation self-efficacy for engineering students interested in creating societal impact. Deeper exploration reveals that certain academic experiences and proximal influences have a direct and significant effect on a student's interest in impact-driven work, and this relationship is strengthened by the partial mediation of innovation self-efficacy. As such, this study suggests that the development of innovation self-efficacy is important in cultivating engineering students who are interested in impact-driven work, and to a lesser extent, financially-driven work. These findings have implications for how engineering educators and employers attract, inspire, and equip future engineers, particularly female and under-represented minority students.

Keywords: *engineering career interests, SCCT, impact-driven, humanitarian engineering*

1.0 Introduction

A central role of engineering is to meet the needs of humanity, and humankind currently faces a variety of challenges, e.g. economic inequality is increasing in the United States (Saez & Zucman, 2016); there are more people in the world with a mobile phone than access to a latrine or toilet (Niemeier, Gombachika, & Richards-Kortum, 2014) and approximately 3 billion people worldwide still burn biomass to prepare their food, posing significant challenges to human health and the environment (Mattson & Winter, 2016).

Engineering has a long history of developing solutions that meet societal needs – from the Roman aqueducts of Segovia to the Folsom Hydroelectric Powerhouse of 1895, the development of xerography in 1948, and Greatbatch's invention of the pacemaker in 1962 (Jurado, 1995; ASME, 1976; ASME, 1983; Greatbatch, 1962). This remains evident today through the development of renewable energy systems and movements such as environmentally sustainable design and humanitarian engineering. While there has been less pro bono engineering work than other professions (Moulton, 2010), the past decade has witnessed a proliferation of organizations that support professional engineering volunteerism, e.g. Engineers Without Borders and Engineers for a Sustainable World, in addition to university-based engineering service learning programs that provide experiential education while working to address societal challenges e.g. EPICS at Purdue; Humanitarian Engineering at Colorado School of Mines, Penn State and Ohio State; D-Lab and Tata Center at MIT; Design for Extreme Affordability at Stanford; and more.

Humanity faces complex global challenges, and there is anecdotal evidence that engineering students are interested in working to address such challenges, but to what extent does this translate into the career interests of current engineering undergraduates? What are the background characteristics, academic experiences, and proximal influences on a college campus that may influence engineering students' interests in pursuing a career involving impact-driven work? What role does innovation play in shaping societal impact intent? These questions have implications for how engineering educators and employers attract, inspire, and equip future engineers.

2.0 Background

2.1 Societal Impact and Impact-Driven Engineering

Extensive literature covers the challenges facing society today. The United Nations has put forth the Sustainable Development Goals (SDGs) of 2015-2030 ranging from achieving food security to promoting just, peaceful and inclusive societies (United Nations, 2015). More specific to engineering, the National Academy of Engineering announced a list of fourteen Grand Challenges for Engineering in the 21st century (NAE, 2008) which include affordable solar energy, access to clean water, and advancement of personalized learning. Societal challenges can be categorized into three types: environmental, social, and economic (Goodland, 1995), and thus societal impact may be defined as measurable effects on environmental, social or economic issues facing human wellbeing and/or the planet. These three categories of societal impact and their connection to engineering are described as follows.

Environmental sustainability is defined as "holding the scale of the human economic subsystem to within the biophysical limits of the overall ecosystem on which it depends" (Goodland, 1995). This involves maintaining natural capital with attention to inputs ("sources") and wastes ("sinks") while considering the sustainable levels of production and consumption. Engineers have a history of contributing both positively and negatively to environmental sustainability, though in recent decades, engineers have placed significant attention on producing positive environmental impacts ranging from increasingly efficient photovoltaic cells (Green, Emery, Hishikawa, Warta, & Dunlop, 2015), advances in sustainable manufacturing (Gutowski *et al.*, 2005), green product innovation (Dangelico & Pujari, 2010), to green materials and eco-informed material choice (Ashby, 2012).

Social sustainability, according to Goodland (1995), is "achieved only by systematic community participation and strong civil society. [It involves] cohesion of community, cultural identity, diversity[…], commonly accepted standards of honesty, laws[…] and requires maintenance and replenishment by shared values and equal rights." Akin to environmental sustainability, engineers across history have impacted social sustainability positively and negatively, and, in recent years, engineers have begun to embrace explicit considerations for promoting positive social impact. In 2008, the National Academy of Engineering hosted a workshop on "Engineering, Social Justice, and Sustainable Community Development." One participant of this workshop, Professor Juan Lucena articulated a reason why engineers are paying increased attention to social sustainability: "Successful humanitarian and community development requires attention to the social dimensions that influence the successful adoption of a technology; to community capabilities rather than deficiencies; to interrelationships and interdependencies in communities; and to the need for community ownership and buy-in" (NAE, 2010). In 2007 Charles Vest, former President of MIT and the National Academy of Engineering, noted: "this current generation of young people[…] very much want to make the world a better place and very few of them see or understand engineering as a mechanism for doing that" (NAE, 2007). Increased attention to social impact in engineering is evident in engineering literature (Austin-Breneman & Yang, 2013; Baillie, Pawley, & Riley, 2012; Mattson & Wood, 2014; Mattson & Winter, 2016; Schafer, Parks, & Rai, 2011) as well as engineering education literature (Lucena, 2013; Sandekian, Chinowsky, & Amadei, 2014; Litchfield & Javernick-Will, 2015; Litchfield, Javernick-Will, & Maul, 2016). However, to date, many engineering and social sustainability efforts have had mixed success (Wood & Mattson, 2016), and engineers, students, and educators would be wise to be mindful that their well-intentioned efforts can do harm (Litchfield & Javernick-Will, 2016; Starr, 2017; Anderson, 1999).

Economic sustainability is commonly defined as the "maintenance of capital" and can be viewed as an extension of Hicks' definition of income: "the amount one can consume during a period and still be as well off at the end of the period" (Hicks, 1946). Engineers have a tradition of producing economic impact – often through technological innovation and industrialization. Economic sustainability can be an end in itself or a means of producing lasting social or environmental impact. For example, within the business community, Prahalad re-framed challenges in Base of the Pyramid (BoP) markets (areas of extreme economic poverty) as areas of emerging, high-growth market potential (Prahalad, 2009). As of 2008, BoP markets represented an estimated US $5 trillion of demand (Subrahmanyan & Tomas Gomez-Arias, 2008). As for-profit corporations expanded into BoP markets, social entrepreneurship and the impact investment industry also emerged aiming to attain profitable returns while measurably advancing a social and/or environmental mission (Martin & Osberg, 2007; Brest & Born, 2013). As of 2011, more than 148 academic institutions globally offered a social entrepreneurship course or program (Brock & Kim, 2011), and over the past two decades, impact investing has grown significantly with a four-quarter rolling average of over US$5 billion invested by the 51 firms in the Impact Investing Benchmark (Matthews, Sternlicht, Bouri, Mudaliar, & Schiff, 2015). While this attention has attracted many new product development efforts to address environmental or social challenges, for-profits have had mixed success in profitability and genuinely advancing environmental causes or serving low-income customers. In response, Hart and Simanis (2008) and Duke and Simanis (2014) have developed tools to assist mission-driven businesses to co-create shared value with their customers and thereby achieve lasting positive social or environmental impact while not losing sight of scalability and profitable unit economics. Overall, creating positive societal impact is of increasing interest to business and finance communities, and the economic sustainability of these efforts is essential.

Taken together, the above research provides a window into the varied challenges facing society. Engineering can play an important role in addressing such challenges. Furthermore, some engineering students are interested in creating positive societal impact – but who are these students, and to what extent are they interested in impact-driven work?

2.2 Impact-Driven Interest as a Career Choice

There are many capacities in which one may address societal challenges, e.g. as a volunteer, employee, and/or founder. To narrow the scope, the current study explores how engineering undergraduates consider addressing societal challenges as a career choice.

In the early 1990's Robert Lent proposed a model of career choice called Social Cognitive Career Theory (SCCT, see Figure 1) that provides a framework for understanding, explaining, and predicting the processes through which people develop occupational choice (Lent & Brown, 2006; Lent, Brown, & Hackett, 1994). The SCCT model has been shown to be useful in predicting career choice among post-secondary students, particularly engineering students (Chubin, Donaldson, Olds, & Fleming, 2008; Lent *et al.*, 2005; Lent, Singley, Sheu, Schmidt, & Schmidt, 2007) which makes it relevant for this study.

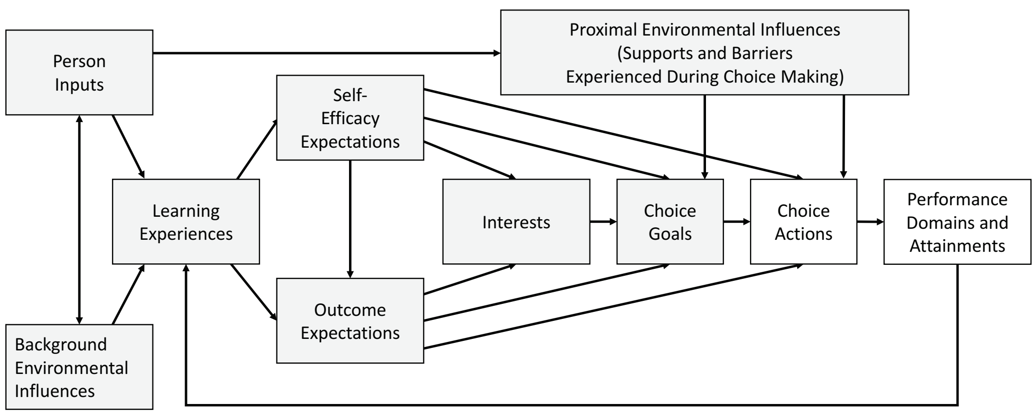

Figure 1: Lent's (1994, 2006) Social Cognitive Career Theory (SCCT) model.

The SCCT model posits that vocational or career goals are a function of several social-cognitive variables, such as self-efficacy, outcome expectations, person inputs, interests, and background and environmental influences. Essentially, person inputs, background influences and learning experiences combine to predict self-efficacy and career outcome expectations. These, in turn, predict career interests and ultimately career choice. The current study uses the SCCT framework to better understand the precursor correlates for an engineering undergraduate's interest in pursuing societal impact as part of their career following graduation.

Prior research has examined students' motivations to study engineering. For example, Sheppard *et al*. tested six motivational influences of engineering students: financial motivation; social good motivation; parental influence; mentor influence; intrinsic psychological and intrinsic behavioral motivations (2010). Among the 1,130 engineering seniors surveyed, intrinsic psychological motivations ("motivation to study engineering for its own sake, to experience enjoyment that is inherent in the activity") and intrinsic behavior motivations ("motivation related to practical and hands-on aspects of engineering") contributed the most. Next in line were social good ("motivation to study engineering due to the belief that engineers improve the welfare of society") and financial motivation ("motivation due to the belief that engineering will provide a financially rewarding career"), with mean social good and mean financial motivation scores of 74.3/100 and 65.2/100 respectively. These findings suggest that societal impact plays a large role in students' motivations to study engineering. As will be described, the current study verifies this result with a large nationally-representative sample of engineering undergraduates.

Gender has been shown to be an important contributing factor for engineers interested in societal impact, altruism, and social-oriented work more generally. There is extensive literature in education and psychology showing significant motivation and identity differences between men and women (Meece, Glienke, & Burg, 2006) including in the context of engineering (Faulkner, 2007; Eccles, 2007). Eccles hypothesized that engineering appeals less to women because they have strong "humanistic and helping values" and that engineering among other STEM career options is often perceived as not sharing these values. In studying a subset of engineering students and professionals participating in impact-driven work (Engineers Without Borders USA) and those not participating in such work, Litchfield and Javernick-Will (2015) found that women were over-represented in their impact-driven sample. However, in analyzing a sample of engineering students and professionals not involved in impact-driven work, they found that women did not show stronger "social good" motivations than men. Overall, their results suggest that there is more at play than gender alone as the humanistic and altruistic aspects of engineering are important for some men and many, but not all, women. Further understanding of students' value systems and their perceptions of value systems within the engineering profession is critical to understanding their motivation to study and persist in engineering.

It should be noted that motivation for societal impact versus financial potential has been studied in public sector, non-profit, and private sector employees and similar primary motivations were found for employees in all three sectors, e.g. financial stability and job security, challenging work, autonomy, skilled supervision and personal growth (Gabris & Simo, 1995). However, significant differences were found in employees' individual needs/desires to attain positions of authority and to compete and win (strong in private and public, low in non-profit); desire for responsibility and to help (strong in public and non-profit, low in private); and desire for feedback and a sense of community (strong in non-profit, low in public and private). Similar to Gabris and Simo, the present study considers interest in societal impact and interest in financial potential as dependent variables.

2.3 Measuring Impact-Driven and Financially-Driven Interests as Career Choices

This research is part of a broader NSF-funded effort to better understand the current landscape of U.S. engineering undergraduates, including their interests, career goals, and confidence in skills and abilities related to innovation and entrepreneurship. This research process began with the Engineering Majors Survey (EMS) 1.0, the first survey of a series administered between March and May 2015 as part of a nationwide, multi-year, longitudinal tracking study.

EMS was developed using SCCT as the conceptual framework. EMS 1.0 asked about background experiences and person inputs, high school and undergraduates coursework and experiences, as well as proximal influences, including the use of faculty and peers as resources for sharing. The survey also included several constructs unique to the SCCT model: innovation and engineering task self-efficacy, innovation interests, and a general question about career direction as a proxy for career choice. The respondents were pre-graduation, so career choice was not known, however this has been the focus of EMS 2.0 and will be tackled in a future EMS

3.0 survey conducted post-graduation. A list of the 71 variables from EMS 1.0 included in this study is shown in Appendix A.1.

The measurement of interest in societal impact was included as part of the Innovation Interest construct question (see Appendix A.2.c). Inspired by previous research comparing engineering students' interest in work that pursues societal impact to work that pursues financial potential (Lintl *et al.*, 2016), two items were appended to the innovation interests question:

How much interest do you have in:

1. *Working on products, projects, or services that address societal challenges*
2. *Working on products, projects, or services that have significant financial potential*

Respondents selected a response from a five point (0-4) Likert scale ranging from "very low interest" to "very high interest". The first item measures interest in work that addresses societal challenges, thus expressing an interest in societal impact (iSI). Students with high iSI are referenced as "impact-driven". The second item measures interest in work that has significant financial potential (iFP). Students with high iFP are referenced as "financially-driven". iFP was included to serve as possible contrast to iSI, although respondents may be interested in both types or neither type of work. This study takes iSI and iFP as proxies for the dependent variable of career choice in the SCCT model and examines the demographic and behavioral correlates – person inputs, background experiences, learning experiences, and proximal influences – that contribute to career choices that pursue impact-driven and/or financially-driven work.

3.0 Research Questions

This study addresses three research questions:

> **RQ 1:** Who are the U.S. engineering students interested in work that addresses societal challenges (impact-driven), and who are those interested in work with significant financial potential (financially-driven)?
>
> **RQ 2:** Which background and academic experiences predict interest in impact-driven work, and which predict interest in financially-driven work?
>
> **RQ 3:** What is the role of innovation interests and innovation self-efficacy in predicting interest in impact-driven work?

4.0 Methods

EMS 1.0, the first part of a nationwide, multi-year, longitudinal tracking study, was administered between March and May 2015. The survey data is comprised of a nationally-representative sample of 27 U.S. engineering institutions (see Appendix A.3) selected from the 350 U.S. institutions with an American Society of Engineering Education member engineering school as of 2011. The survey was completed by 6,187 undergraduate engineering students[1] and after data cleaning and imputation, resulted in a complete sample of 5,819 juniors, seniors and 5th year engineering students, as shown in Table 1.

Table 1: EMS 1.0 Analysis Sample Demographics

	Total Sample		Class Standing			Under Represented	First Generation
Unweighted	**n**	**%**	**Junior**	**Senior**	**5th Year**	**Minority**	**College**
Male	4,097	70.4%	1,937	1,638	522	553	693
Female	1,722	29.6%	777	746	199	274	239
Total	5,819	100.0%	2,714	2,384	721	827	932

In this sample, all respondents were enrolled undergraduate engineering students, 30% female, 14% underrepresented minorities and 16% first generation college students.[2] For a complete discussion of the EMS study, please refer to the EMS Technical Manual (Gilmartin et al., 2017).

EMS 1.0 employed various types of questions. Academic learning experiences and activities were asked as "participation" questions, resulting in a binary (yes – 1, no - 0), self-efficacy construct questions were asked using a Likert "confident can do" scale (0 – not confident, 4 – highly confident), engineering career persistence was asked using a Likert "will not/will" scale (0 – definitely will not, 4 – definitely will) and proximal influences were assessed using a Likert frequency scale (0 – never, 4 – very often).

This data set contains four constructs that correspond to specific nodes in the SCCT model (see Figure 1). These constructs are described as follows, and shown in detail in Appendix A.2.

Innovation Self-Efficacy (ISE.5) – This self-efficacy construct involves specific behaviors that characterize innovative people and is designed to measure a students' confidence in his/her ability to innovate. The included items are adapted from Dyer, Gregersen, and Christensen (2008). The original Dyer items were piloted and factor-analyzed as part of the EMS survey development process. The emergent five factors corresponded to Dyer's innovative behavior domains of questioning, observing, experimenting, and idea networking, as well as the related domain of associative thinking. These items each have a Likert scale of (0-4), have an acceptable Cronbach α (.78), and have been averaged to form the ISE.5 construct variable (Schar, Gilmartin, Rieken, Harris, & Sheppard, 2017).

Engineering Task Self-Efficacy (ESE) – This self-efficacy construct is designed to measure a student's confidence in his/her ability to perform integral technical engineering "tasks" such as "analyzing the operation or functional performance of a complete system." It is composed of five items that were identified from a factor analysis of a longer list of engineering task items used in

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[1] The analysis data set contained 96.5% complete data. It was determined that the missing data was missing completely at random (MCAR) and multivariate imputation by chained equations (MICE) was used with predictive mean matching (PMM) and 5-iterations to complete the data set.

[2] For the purposes of this study, underrepresented minority (URM) is defined as any respondent who indicated a Latino/a, African American, Native American or Pacific Islander ethnicity. First Generation College (FGC) is defined as any respondent where both the mother/female guardian and father/male guardian had less post-secondary education than an Associate degree. This is regarded as a broader definition of FGC students. (Auclair et al., 2008; Choy, 2001; Toutkoushian, Stollberg, & Slaton, 2015)

Fouad and Singh's work on engineering career outcomes (2011), and were first deployed in the Pathways of Engineering Alumni Research Survey (PEARS) (Chen *et al.*, 2012). These items have a good Cronbach α (.88) and have been averaged to form the ESE construct variable.

Innovative Interests (InI) – This construct integrates Dyer's discovery-based behaviors (2008) and Kanter's description of innovation tasks by expressing interests common to the work place (1988). The Innovative Interests construct question was asked using a Likert "interest" scale (0 – very low interest, 4 – very high interest). The five items (not including iSI and iFP)[3] have an acceptable Cronbach α (.78) and have been averaged to form the INI construct variable.

Career Goals: Innovative Work (CGIW) – This is the primary outcome measure of the original SCCT model, as specific career choice had not been made by the respondents. The six items are an adaptation of Kanter's innovation tasks (1988) to the individual-level behaviors in Scott and Bruce (1994) and the Young Entrepreneurs Survey (Lerner & Damon, 2011). These items were modified such that they are measured on an importance scale, rather than a frequency scale, to better approximate "career goals" in SCCT. The six items have a good Cronbach α (.85) and have been averaged to form the CGIW construct variable.

For this study, differences in means were tested using Cohen's *d* effect size (Cohen, 1988) and the significance threshold for all analysis is $p < .05$. Linear regression and structural equation modeling were done in R using a variety of packages.

5.0 Results

The findings are organized by research question (from section 3) as follows.

5.1 RQ 1: *Who are the engineering students interested in work that addresses societal challenges (impact-driven), and who are those interested in work with significant financial potential (financially-driven)?*

Responses to the questions about interest in societal impact (iSI) and interest in financial potential (iFP) have a normal distribution with a negative skew, as shown in Figure 2. In total, 70% of respondents indicated a "high" (3) to "very high" (4) interest in impact-driven work compared to 65% of respondents with a similar rating for interest in financially-driven work. There is a modest positive and significant correlation between iSI and iFP (r = .35, p < .00), indicating that some students felt similarly positive or negative about these two career options though in total, only about 12% of the variance in iSI is explained by iFP.

[3] As stated, this study employs the five-item measure of Innovation Interests (INI) which differs from the original seven-item Innovation Interests (INI.7) measure (Gilmartin et al., 2017).

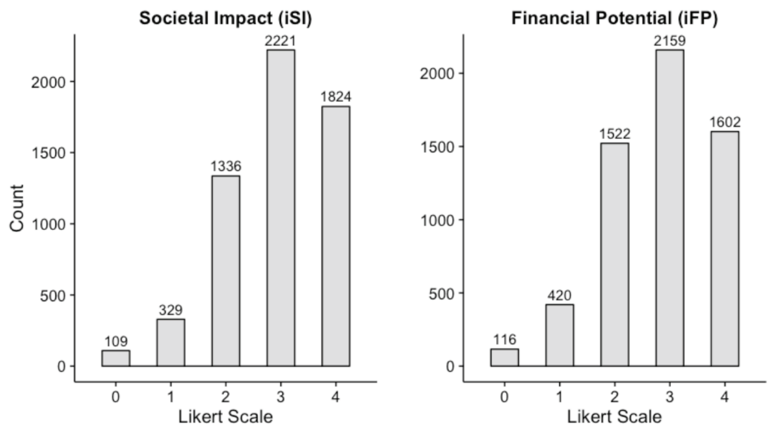

Figure 2: Histogram of Responses to Interest in Societal Impact (iSI) and Interest in Financial Potential (iFP)

The mean score for iSI is 2.91, which is not significantly different than the mean score of 2.81 for iFP, as shown in Table 2. This finding is consistent with (Sheppard et al., 2010). However, the mean score for iSI among females is 3.05, which is significantly higher (*diff.* =. 48, *d* = .50) than the mean score for iFP among females 2.57. The female iSI score is also higher than the iSI score for males (*diff.* = .19, *d* = .21) and the female score for iFP is lower than the iFP score for males (*diff.* =.34, *d* = .36). URM respondents have a higher iSI score than non-URM respondents (*diff.* =.19, *d* = .20). There is no difference in iSI or iFP scores among first generation college students and their counterparts.

Table 2: Item Means for Interest in Societal Impact (iSI) Compared to Interest in Financial Potential (iFP)

	Total	Male	Female	diff	*d*	URM	≠URM	diff	*d*	FGC	≠FGC	diff	*d*
n	*5,819*	*4,097*	*1,722*			*807*	*5,012*			*932*	*4,887*		
Impact (iSI)	2.91	2.86	3.05	**-.19**	**.21**	3.08	2.89	**.19**	**.20**	2.89	2.92	-.03	.03
Financial (iFP)	2.81	2.91	2.57	**.34**	**.36**	2.95	2.79	.16	.06	2.88	2.80	.08	.08
Difference	.10	-.05	**.48**			.13	.10			.01	.12		
Cohen's *d*	.11	.06	**.50**			.13	.10			.01	.13		

The finding that women and URM students compared to other engineering students are more interested in impact-driven work is supported by the literature. Through studying intergenerational differences in STEM career development at U. Mass. Lowell, Rayman found that women tend to be inclined to work on social, community, and global issues (2007). Additionally, engineering disciplines with a greater service ethic, e.g. biomedical and environmental engineering, tend to have higher percentages of women than other engineering disciplines (U.S. Bureau of Labor Statistics, 2017). Finally, as discussed in section 2.2, in studying students engaged in Engineers Without Borders USA, Litchfield and Javernick-Will found that the humanistic and altruistic aspects of engineering are motivating factors for some men and many, but not all, women (2015). They suggest further investigation into factors other than gender that may influence these motivational interests, such as cognitive style (empathic vs. systemizing) which was found to be a significant predictor of students studying the humanities versus the sciences, regardless of their sex (Billington, Baron-Cohen, & Wheelwright, 2007). The main goal of the current study is to understand the behavioral correlates that lead to impact-driven work as a career choice.

5.2 RQ 2: *Which background and academic experiences predict interest in impact-driven work, and which predict interest in financially-driven work?*

Linear regression was used to predict the relationship between interest in societal impact (iSI) and the range of person inputs, background experiences, academic experiences, proximal influences and self-efficacy constructs – 71 variables in all. The process involved building successive regression models, each discarding variables of lesser influence on the prediction outcome, until a core of the most significant variables remained, as shown in Table 3. The first step was to create a linear regression model where all 71 independent variables were used to predict the variance in the dependent iSI variable, resulting in a .237 adjusted r^2 model fit, forming the baseline fit measure.

Table 3: Results from Item Reduction by Linear Regression

	Societal Impact (iSI)			Financial Potential (iFP)		
Method	**# Items**	**Adj r^2**	**AIC**	**# Items**	**Adj r^2**	**AIC**
All Variables	71	.237	15010	71	.294	14559
Step-Wise	31	.234	14961	27	.295	14503
Optimized	14	.231	15003	13	.290	14507

Next, step-wise linear regression was performed using the Akaike Information Criterion (AIC) (Akaike, 1974) value as a measure of goodness of fit of the model, and a reduction indicator. As shown in Table 3, this allowed for a reduction of the independent variables from 71 to 31 without compromising overall model fit (AIC value). The final model was optimized by removing any independent variables with $p < .05$ significance, and the resulting optimized model has 14 independent variables predicting the iSI dependent variable and a good model fit (adjusted r^2 = .231) which is statistically equivalent to the original model with all 71 variables. For comparison, the same process was completed for the dependent variable interest in financial potential (iFP).

The resulting optimized fit model is shown in Table 4. The most important predication variables for iSI, as measured by the standardized B coefficients, is the construct of innovative interests (*B* = .34), followed by the construct of career goals: innovative work (*B* = .08) and the related construct of innovation self-efficacy (*B* = .05). Not surprisingly, the activity of "participated in a service-based club" as an undergraduate (*B* = .06) is also a significant predictor of interest in impact-driven work.

In describing the factors that predict interest in impact-driven work, there appear to be themes of innovation (Innovation Self Efficacy *B* = .05, Innovation Interests *B* = .34); creating ("computer programming *B* =.03, "designing/prototyping ideas" *B* =.03); service ("participating in service-based clubs" *B* = .06); broadening oneself outside of engineering ("studying abroad" *B* =.03, "interacting with non-engineering majors" *B* =.04); and learning versus career ("discussing course topics with peers" *B* =.04, versus "discussing career options with peers" *B* =.00). In terms of person inputs, being female (*B* = -.09, Male =1, Female = 0) and from an underrepresented minority (*B* = .03, Yes = 1, No = 0) are also significant predictors of interest in impact-driven work. The only academic major that predicts iSI is being a civil engineering major (*B* = .04). Also, expected persistence in engineering one year after graduation is a predictor of interest in impact-driven work (*B* = .06).

Finally, in terms of proximal influences, one interesting variable proved significant – the number of business start-ups per 1,000 population (kpop) in the Metropolitan Statistical Area (MSA) surrounding the location of the campus. This variable was created using Business Dynamic Statistics from the U.S. Census Bureau (2013) which reports the number of start-up businesses per kpop by MSA. This is viewed as an indicator of the "entrepreneurial climate" in the community surrounding the campus. The significance of this variable suggests that the proximal influences of a campus can include the surrounding community and in this case, a "start-up atmosphere" may be appealing to students with an interest in impact-driven work, despite "learning about entrepreneurship" not being a significant predictor of iSI.

Table 4: Optimized Linear Regression of Person Inputs, Background Experiences, Academic Experiences and Proximal Influences Predicting Interest in Societal Impact (iSI) and Financial Potential (iFP)

Direct Variable →	**Societal Impact (iSI)**				**Financial Potential (iFP)**			
Term	***B***	***SE***	**t**	**p**	***B***	***SE***	***t***	**p**
Learning Experiences - High School								
Learn about entrepreneurship					.04	.01	3.39	.00
Learn computer programming					-.02	.01	-2.02	.04
Undergraduate Coursework								
Computer programming	.03	.01	2.35	.02				
Designing/prototyping ideas	.03	.01	2.93	.00				
Interaction w non-eng. majors	.04	.01	3.01	.00				
Business or enterprise topics					.05	.01	4.70	.00
Major - CE (1 - Yes, 0 - No)	.04	.01	3.46	.00				
Major - IE (1 - Yes, 0 - No)					.03	.01	3.06	.00
Undergraduate Activities								
Participate in study abroad	.03	.01	2.60	.01				
Participated in service-based club	.06	.01	5.17	.00				
Conduct research w. faculty					-.06	.01	-5.51	.00
Proximal Influences								
Discuss course topics w. peers	.04	.01	3.06	.00				
Start-ups/kpop (MSA)	.03	.01	2.52	.01				
Discuss career options w. faculty					-.07	.01	-5.57	.00
Discuss career options w. peers					.06	.01	4.88	.00
Self-Efficacy								
Innovation Self-Efficacy	.05	.01	3.63	.00				
Engineering Self-Efficacy					.10	.01	7.68	.00
Interests								
Innovation Interests	.34	.02	21.43	.00	.23	.02	15.31	.00
Career Goals Innovative Work	.08	.02	4.91	.00	.23	.01	15.73	.00
Engineering Persistence - 1 year	.06	.01	4.62	.00	.07	.01	5.96	.00
Demographics								
Gender (1 - Male, 0 - Female)	-.09	.01	-7.50	.00	.11	.01	9.87	.00
URM (1 - Yes, 0 - No)	.03	.01	2.33	.02	.03	.01	2.38	.02
Items	14				13			
Summary	**Adj r^2**	**AIC**	**t**	**p**	**Adj r^2**	**AIC**	**t**	**p**
	.23	15003	125.71	.00	.29	14507	183.78	.00

n = 5,819; *B* coefficient and *SE* standardized (centered and scaled)

A similar analysis process was completed using interest in financial potential (iFP) as the dependent variable for comparison purpose. Similarities with the iSI analysis included the significance of Innovative Interests (*B* = .23), Career Goals Innovative Work (*B* = .23) and perceived Engineering Persistence (*B* = .07). Not surprisingly, the high school experience of "learning about entrepreneurship" (*B* = .04) and undergraduate coursework on "business or enterprise topics” (*B* = .06) are significant predictors of interest in financial potential. Being male (*B* = .11) or from an underrepresented minority (*B* = .03) are also significant predictors of interest in financial potential.

Academically, majoring in industrial engineering is a significant predictor (*B* = .03), as is a reluctance to engage with faculty either to “conduct research with faculty” (*B* = -.06) or to “discuss career options with faculty” (*B* = -.07). Finally, the engineering task self-efficacy measure (*B* = .10) is a significant predictor, suggesting that students that focus more on engineering task skills are attracted to career opportunities with greater financial potential.

5.3 RQ 3: *What it the role of innovation and innovation self-efficacy in predicting interest in societal impact (iSI)?*

The previous analysis suggests the importance of a service ethic and broadening oneself outside of engineering in the development of interest in impact-driven work. It also suggests that innovation self-efficacy is an important predicting characteristic. The question then is how does the undergraduate academic experience (defined as courses taken, activities and the proximal influences that exist on campus) interact with a student’s sense of innovation capability to predict an interest in impact-driven work?

This analysis began with looking at post-secondary academic learning experiences and proximal influences (Appendix A.1: variables #12-35, 46-52 and 66-71) that may predict interest in impact-driven work. These 37 variables were regressed against interest in societal impact (iSI) and the results (as measured by standardized *B* coefficients) show that five variables emerge as significant predictors as measured by the standardized B coefficients (see Table 4). Three of these five variables are proximal influences (#70: Discuss with peers: professional options, #71: Discuss with peers: new design or business idea, #66: Discuss with faculty: course topics and assignments), one variable suggests an interest in gathering information on innovation (#27: Attended a presentation on entrepreneurship or innovation) and one variable directly relates to community service (#17: Participated in a community service-based club).

Structural equation modeling was used to determine the mediation effect of innovation self-efficacy on the relationship between the societal impact measures and interest in impact-driven work. As expected, academic experiences and proximal influences have a direct and significant impact on a student’s interest in work that has societal impact (c’:*B* = .26) and this relationship is strengthened by the partial mediation of innovation self-efficacy (c:*B* = .33, $p < .00$), as shown in Figure 3. This relationship suggests that enhancing a student’s sense of innovation capability will have a significant and positive impact on their corresponding interest in impact-driven work.

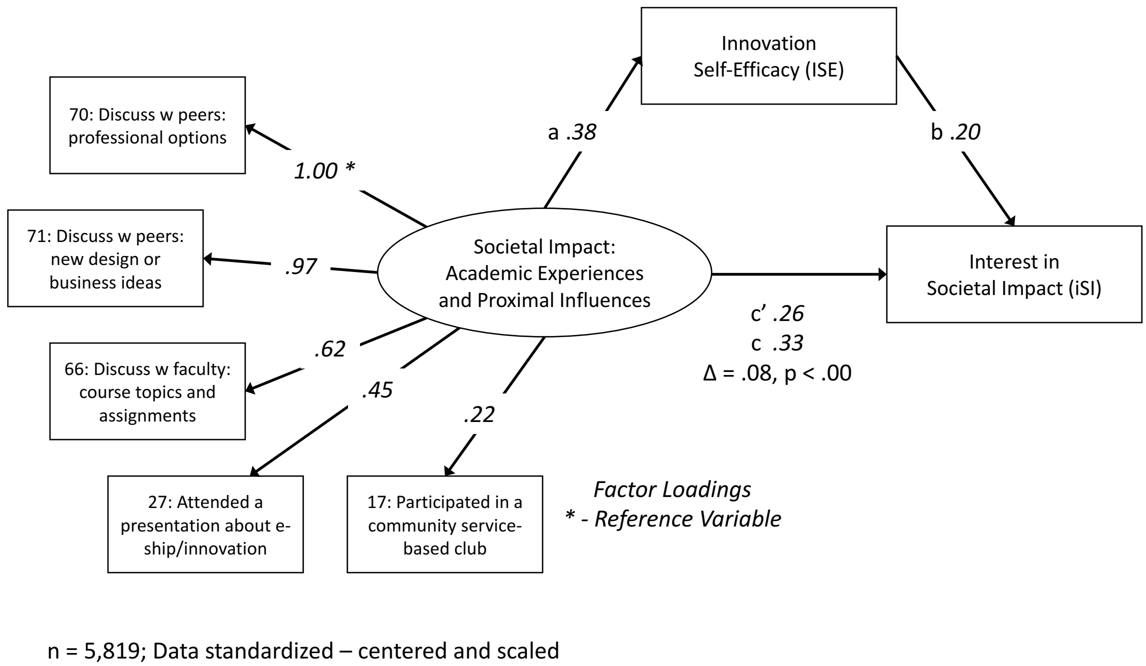

Figure 3: SEM/Mediation Model showing the Impact of Innovation Self-Efficacy on Relationship between Academic Experiences and Proximal Influences on Interest in Societal Impact (iSI)

5.4 Limitations

This study hinges on respondents rating their interest in "working on projects, products or services that address societal challenges" and "… that have significant financial potential." The terms "societal challenges" and "financial potential" may be interpreted in many ways. For example, a project, product, or service may have significant financial potential for an economy, an employer, the respondent and one's family, or a user/customer. Similarly, what constitutes a societal challenge can vary widely – from addressing climate change, social injustice, extreme global poverty to issues related to education or family cohesion within one's local community. Analysis of qualitative responses and follow-up interviews may reveal a deeper understanding of what motivates impact-driven students, financially-driven students, and students motivated by both or neither.

Additionally, the current analysis has identified the following constructs as significant in predicting interest in impact-driven or financially-driven work: Innovation Interests, Innovation Self-Efficacy, Engineering Task Self-Efficacy, and Career Goals Innovative Work. These constructs are composite variables consisting of a variety of items, as shown in Appendix A.2. Further analysis could reveal which construct sub-items are most important in predicting interest in impact-driven and/or financially-driven work.

6.0 Discussion

A nationally-representative survey of U.S. engineering undergraduates found that 70% of respondents indicated high or very high interest in work that addresses societal challenges (iSI) compared to 65% of respondents with a similar rating for interest in work with significant financial potential (iFP). There was a modest positive and significant correlation between iSI and iFP ($r = .35$, $p < .00$), indicating that some students felt similarly positive or negative about these two career options. This finding is in line with previous research (Sheppard *et al.*, 2010), thereby providing further evidence that a large majority of current engineering undergraduates are motivated to pursue careers that address societal challenges, and that have significant financial potential.

This study also confirms prior research that identifies gender as a significant factor in predicting interest in impact-driven work. Female engineering undergraduates are significantly more interested in work that addresses societal challenges than work that has significant financial potential. Additionally, compared to their male counterparts, female engineering students are more interested in impact-driven work and less interested in financially-driven work. Finally, URM respondents were more interested in impact-driven work than non-URM respondents, and there was no difference in interest in societal impact or financial potential among first generation college students and their counterparts.

This study focuses on students' background and academic experiences that predict interest in impact-driven and financially-driven work. Through linear regression, it was found that experiences promoting a service ethic and broadening oneself outside of engineering are important predictors of interest in impact-driven work. What is less expected is the significant importance of Innovation Interests and Innovation Self-Efficacy for students interested in impact-driven as compared to financially-driven work. Deeper exploration reveals that academic experiences and proximal influences (e.g. discussing new design/business ideas with peers, or participation in a community service-based club) have a direct and significant impact on a student's interest in impact-driven work, and this relationship is strengthened by the partial mediation of Innovation Self-Efficacy. This suggests that enhancing a student's sense of innovation capability will have a significant and positive impact on their corresponding interest in impact-driven work. Likewise, it is expected that strengthening innovation self-efficacy would have a similar (albeit weaker) effect on interest in financially-driven work. It is curious that financially-driven students appear to have an aversion to conducting academic research and discussing career options with faculty. Also, it may be important to consider how to attract financially-driven students with high Engineering Task Self-Efficacy for impact-driven work – or how to increase the Engineering Task Self-Efficacy of impact-driven students.

Overall, this study offers the idea that innovation and the development of innovation self-efficacy are important in cultivating engineering students who are interested in impact-driven work. Also, it confirms findings that women and URM engineering students are more likely to be interested in impact-driven work, and to choose and persist in engineering if this kind of work is available. This has implications for the kinds of curricula, projects, products and services that engineering educators and engineering professionals may consider developing, especially if a greater proportion of female and/or URM engineering students are desired. In particular, schools and employers may consider efforts that cultivate students' or employees' innovation self-efficacy, something that may have many positive effects.

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Appendix

A.1 – Engineering Majors Survey 1.0: Study Variables

#	**Person Interests/Background Experiences**
1	Grade (Junior, Senior, 5th Year)
2	Gender (1 – Male, 0 – Female)
3	Underrepresented Minority (Yes – 1, No – 0)
4	Age - Years
5	Family Income (ordinal)
6	First Generation College (Yes – 1, No – 0)
7	Undergraduate GPA (ordinal)
8	School: Carnegie Class (R1 – 1, $\neq$ 0)
9	School: Size (+2K engineering students – 1, $\neq$ 0)
10	School: City (MSA +250K -, $\neq$ 0)
11	School: Business Start-ups/kpop (MSA)

#	**Learning Experiences – Undergraduate Activities**
12	Conduct research with a faculty member
13	Work in a professional eng. environment as an intern
14	Have a job to help pay for your college education
15	Participate in study abroad
16	Participated in a business or entrepreneurship club
17	Participated in a community service-based club
18	Participated in a design club
19	Participated in a robotics club
20	Participated in student clubs or groups in engineering
21	Participated in student clubs outside of engineering
22	Entered a business plan, or elevator pitch competition
23	Entered a design or invention competition
24	Entered a social entrepreneurship competition
25	Made use of a maker space/ prototyping lab
26	Attended a career related event (e.g., college career fair)
27	Attended a presentation about e-ship/innovation
28	Attended a start-up boot camp
29	Attended a presentation on new engineering technology
30	Lived in a residential engineering community
31	Lived in a residential entrepreneurship community
32	Received funding from a program to finance new ideas
33	Led a student organization
34	Started or co-founded a student club on campus
35	Started your own for-profit or non-profit organization

#	**Self-Efficacy Measures**
36	Engineering Self-Efficacy construct (see Appendix A.3)
37	Innovation Self-Efficacy construct (see Appendix A.3)

#	**Learning Experiences – High School**
38	Take an art, dance, music, theater, creative writing class
39	Learn computer programming
40	Take a shop class
41	Participate in a robotics competition
42	Attend a science/math/engineering summer camp
43	Internship at a science/math/engineering company
44	Learn about entrepreneurship
45	Start/co-found a club, organization, or company

#	**Learning Experiences – Undergraduate Coursework**
46	Art, dance, music, theater, or creative writing
47	Computer science
48	Theory of design
49	Designing and/or prototyping things or ideas
50	Business or enterprise topics
51	Leadership topics
52	Interaction with students from non-engineering majors
53	Major: Aerospace (Yes – 1, $\neq$ 0)
54	Major: Chemical - ChE (Yes – 1, $\neq$ 0)
55	Major: Civil - CE (Yes – 1, $\neq$ 0)
56	Major: Electrical - EE (Yes – 1, $\neq$ 0)
57	Major: Industrial - IE (Yes – 1, $\neq$ 0)
58	Major: Materials - MaE (Yes – 1, $\neq$ 0)
59	Major: Mechanical - ME (Yes – 1, $\neq$ 0)
60	Major: Other Engineering - OE (Yes – 1, $\neq$ 0)

#	**Innovation Interests**
61	Innovation Interests construct (see Appendix A.3)
62	Career Goals: Innovative Work (see Appendix A.3)
63	Engineering Persistence: 1 year post-graduation
64	Engineering Persistence: 5 years post-graduation
65	Engineering Persistence: 10 years post-graduation

#	**Proximal Influences**
66	Discuss w faculty: course topics and assignments
67	Discuss w faculty: professional options
68	Discuss w faculty: new design or business ideas
69	Discuss w peers: course topics and assignments
70	Discuss w peers: professional options
71	Discuss w peers: new design or business ideas

A.2 – Engineering Majors Survey 1.0: Selected Survey Construct Questions

Background on the following EMS 1.0 survey items is described in depth by Gilmartin et al.(Gilmartin et al., 2017).

a. Innovation Self-Efficacy (ISE)

How confident are you in your ability to do each of the following at this time?

Not Confident (0)	Slightly Confident (1)	Moderately Confident (2)	Very Confident (3)	Extremely Confident (4)

1. Ask a lot of questions
2. Generate new ideas by observing the world
3. Experiment as a way to understand how things work
4. Actively search for new ideas through experimenting
5. Build a large network of contacts with whom you can interact to get ideas for new products or services

b. Engineering Task Self-Efficacy (ESE)

How confident are you in your ability to do each of the following at this time?

Not Confident (0)	Slightly Confident (1)	Moderately Confident (2)	Very Confident (3)	Extremely Confident (4)

1. Design a new product or project to meet specified requirements
2. Conduct experiments, build prototypes, or construct mathematical models to develop or evaluate a design
3. Develop and integrate component sub-systems to build a complete system or product
4. Analyze the operation or functional performance of a complete system
5. Troubleshoot a failure of a technical component or system

c. Innovation Interests (InI)

How much interest do you have in:

Very Low Interest (0)	Low Interest (1)	Medium Interest (2)	High Interest (3)	Very High Interest (4)

1. Experimenting in order to find new ideas
2. Giving an "elevator pitch" or presentation to a panel of judges about a new product or business idea
3. Finding resources to bring new ideas to life
4. Developing plans and schedules to implement new ideas
5. Conducting basic research on phenomena in order to create new knowledge
6. Working on products, projects, or services that address societal challenges
7. Working on products, projects, or services that have significant financial potential

Note: Items c.6 and c.7 identify interest in societal impact (iSI) and interest in financial potential (iFP).

d. Career Goals: Innovative Work (CGIW)

How important is it to you to be involved in the following job or work activities in the first five years after you graduate?

Not Important (0)	Slightly Important (1)	Moderately Important (2)	Very Important (3)	Extremely Important (4)

1. Searching out new technologies, processes, techniques, and/or product ideas
2. Generating creative ideas
3. Promoting and championing ideas to others
4. Investigating and securing resources needed to implement new ideas
5. Developing adequate plans and schedules for the implementation of new ideas
6. Selling a product or service in the marketplace

A.3 – Survey Schools and Sample Characteristics

Survey Schools

Arizona State University	Indiana University-Purdue University-Indianapolis	Stanford University	University of Utah
Baylor University	Messiah College	Temple University	University of Wisconsin-Madison
Boise State University	Michigan Technological University	Tennessee Technological University	University of Wisconsin-Platteville
Bucknell University	North Carolina State University at Raleigh	The University of Texas at San Antonio	Washington University in St Louis
California State University-Fresno	Rochester Institute of Technology	Tufts University	Wayne State University
Embry Riddle Aeronautical University-Daytona Beach	Seattle Pacific University	University of Illinois at Urbana-Champaign	Western Michigan University
Franklin W. Olin College of Engineering	Smith College	University of the District of Columbia	