A Social Cognitive Approach to Understanding Engineering Career Interest and Expectations among Underrepresented Students in School-Based Clubs

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Abstract

Interest in engineering at early stages of the educational career is one important precursor to choosing to study engineering in college, and engineering-related clubs are designed to foster such interest and diversify the engineering pipeline. In this study, the researchers employed a social cognitive career theory framework to examine level of interest in studying engineering and expected educational attainment among underrepresented low-income middle and high school students participating in materials science and engineering (MSE) clubs. Questionnaire data were collected from over 200 MSE club participants in low-income public middle and high schools in Puerto Rico. The results indicate that perceived value of engineering is useful in predicting career interest among underrepresented middle and high school students; however, traditional predictors of educational interests and attainment (gender, mother's education, parent expectations) exert the strongest influence on engineering interest and attainment expectations.

The demand for qualified science, technology, engineering and math (STEM) professionals is high and increasing, but the nation's ability to supply individuals for these positions is at risk if currently underrepresented populations are not engaged in these fields (NACME, 2014). Calls to improve K-12 education in the STEM subjects have come from multiple national groups and agencies including the American Association for the Advancement of Science, the National Academies, the National Science Board, and the U.S. Department of Education (AAAS, 1993; NAS, NAE, & IOM, 2007; NSB, 2007; U.S. Department of Education, 2008). As a consequence, state departments of public education are beginning to consider the inclusion of engineering and technology in their curricular standards.

Educational outreach to K-12 students has become an important component of STEM education in the United States, with the aim to support national efforts to increase the participation of underrepresented and underserved groups in STEM fields, based on gender, ethnicity, income, and geography, among other factors. Most STEM-related afterschool programs are designed to trigger and maintain situational interest through engaging hands-on activities, which are critical first steps in the development of STEM interest (Hidi & Renninger, 2006); and many activities are specifically targeted to students from underrepresented groups. Science clubs in traditional fields (such as biology, chemistry, and physics) have been common in school settings for decades, and they are generally viewed as effective for generating student interest and enthusiasm for the subject matter (e.g., Ben-Nun & Yarden, 2009; Gmurczyk & Collins, 2010). These types of clubs can be led by teacher experts given their preparation and experience, and they can be easily linked to the formal curriculum offered in schools. In recent studies of the effects of participation in extracurricular STEM activities and clubs, researchers have found positive relationships between participation and interest in STEM careers in college (Dabney et al., 2012), and further, that higher "dosage" of STEM opportunities in afterschool programs (i.e., more time) is associated with higher science test scores and higher reported interest in science (Noam, Robertson, Papazian, & Guhn, 2014). In a large interview study of science graduate students, the majority reported their interest began before middle school, and women were more likely than men to indicate their interest was piqued by school-related activities (Maltese & Tai, 2010). In turn, longitudinal national data have shown that odds of completing a degree in STEM are significantly increased by expressed interest in a science career in grades 8 and 10, rather than by high school science achievement (Maltese & Tai, 2011). Taken together, this body of research suggests that science club and afterschool participation leads to increased science interest, which increases the odds of STEM degree completion

In contrast to what is known about science interest, research indicates that pre-college students have a limited understanding of who can be an engineer (men) and what engineering work entails (making) (e.g., Fralick, Kearn, Thompson, & Lyons, 2009). Engineering education has traditionally been seen as beginning in college, and the idea of K-12 engineering education has only evolved more recently (Katehi, Pearson, & Feder, 2009), with the development of specialized curriculum (e.g., Project Lead the Way) and engineering-focused magnet schools in large urban centers (e.g., Charlotte, Dallas, Hartford). Accordingly, school-based clubs and activities in engineering have been less commonly available to students. University researchers on the frontiers of these fields are the ideal partners for teachers to introduce students to emerging fields and career opportunities of the future. In this study, we examine an underserved middle and high school sample participating in engineering clubs, and use a social cognitive framework to understand engineering interest and expected attainment among these students.

Social Cognitive Career Theory to Understand Engineering Career Interest

One approach to understanding participation gaps in college attendance utilizes Social-Cognitive Career Theory (SCCT; Lent, Brown, & Hackett, 1994) to help explain achievement and career-related choices. This theory posits that personal characteristics and contextual background factors play a role in determining attainment aspirations and career interests. Person, cognitive, and contextual (environmental) variables directly influence and/or moderate career choice processes and behavior. Maltese and Tai (2011) have used this framework to look at the role of science interest in pipeline persistence in STEM, finding that career interest in high school significantly predicts likelihood of STEM degree completion. Lent and colleagues further suggest that contextual factors are particularly influential for underrepresented groups and have successfully employed the theory to understand engineering interest and goals (Lent, Brown, Sheu, Schmidt, Brenner, Gloster, et al., 2005; Lent, Sheu, Singley, Schmidt, J., Schmidt, L., & Gloster, 2008; Lent, Sheu, Gloster, & Wilkins, 2010), adjustment (Lent, Miller, Smith, Watford, Lim, Hui, et al., 2013), satisfaction (Lent, Singley, Sheu, Schmidt, J., & Schmidt, L., 2007), and persistence (Lent, Brown, Schmidt, Brenner, Lyons, & Treistman, 2003) among college engineering students. Byars-Winston and colleagues (2008; 2010) have similarly examined the science and engineering career choices of underrepresented racial minority students using SCCT, and Martin (formerly Trenor) has also employed the framework to understand persistence of ethnic minority women in engineering (Martin, Yu, Sha, Waight, & Zerda,

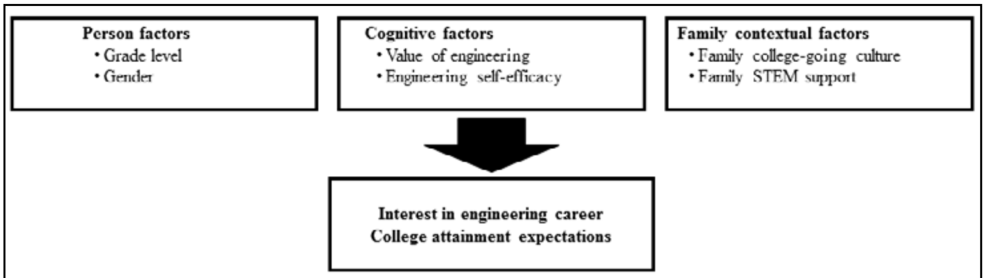

Figure 1. Social cognitive career theory conceptual framework to understand engineering interest and attainment expectations among underrepresented low-income Latino middle and high school students

2007; Trenor, Yu, Sha, Zerda, & Waight, 2008).

Over the past decade, researchers have begun to use SCCT to predict career interests and aspirations of middle and high school students, particularly among underrepresented and underserved groups. Ojeda and Flores (2008) found support for the role of contextual factors in predicting educational aspirations among Mexican American high school students. Nauta and Epperson (2003) used a longitudinal SCCT-based design to predict choice of a science, engineering, or math (SEM) college major among female high school students who were enrolled in an SEM conference. A study by Navarro, Flores, and Worthington (2007) found that math/science self-efficacy and outcome expectations predicted math/science career interests and goals among Mexican American middle school students. Garriott, Flores, and Martens (2013) employed the theory to predict the math/science goal intentions of low-income prospective first-generation college students. However, research using an SCCT framework to predict interest in engineering among underrepresented middle and high school students is lacking in this growing literature.

In the present study, we utilized a conceptual framework that emphasizes the role of person, cognitive, and contextual variables in the development of youth interest in studying engineering and educational attainment expectations (Figure 1). The primary research question for the study was: To what extent do person factors, cognitive factors, and contextual factors explain student educational aspirations, in terms of interest in pursuing engineering studies and attainment expectations?

While the sample for the study includes engineering club participants, it is important to clarify that the purpose of the study is not to evaluate how engineering interest is affected by club participation or activities. Rather, we aim to understand how person, cognitive, and contextual factors contribute to engineering interest among this specific sub-population.

Methodology

MSE Clubs and Research Setting

Since 2005, faculty members and students from University of Puerto Rico at Mayagüez (UPRM), a four-year public institution in Puerto Rico, have worked with science teachers at local public middle and high schools to form materials science and engineering (MSE) student clubs through two consecutive NSF-funded projects in materials science and nanotechnology research. In 2005, the first clubs were established in two high schools in collaboration with two teachers who had participated in a summer research program connected to the first project, and by 2007, clubs had been established in seven high schools. In the first year of the second project, six additional middle school clubs were formed, expanding the MSE club concept to middle school. At the time of data collection for this study, a total of 11 clubs were operating, involving 320 students (142 high schools and 178 intermediate). All of the schools serve low-income Latino student populations, with 60%-93% of students below the poverty level, as reported to the Puerto Rico Department of Education. According to the 2012 American Community Survey, the percentage of the adult population who have attained a four-year degree ranges is about 24% in the municipalities where the research was conducted, which is comparable to the average attainment for all of Puerto Rico, but several percentage points lower than the US average (29.1%).

Participants

As part of club participation, students completed assessment

Variables	Possible scores	Mode (%)	Mean (SD)
Person factors			
▪ Gender	0=male, 1=female	Male (61%)	
▪ Grade level	7, 8, 9, 10, 11, 12	7 (31%)	
Cognitive factors			
▪ Studying engineering is worth the effort	1=agree, 0=disagree	Agree (96%)	
▪ Like science and math courses more	1=agree, 0=disagree	Agree (72%)	
▪ Engineering self-efficacy (I like figuring out how things work, I consider myself to be a creative person, I have good problem-solving skills, I like to work with technical things)	Sum of agree responses (range 0-4) 1=agree, 0=disagree		3.49 (0.84)
Family college-going culture			
▪ Mother's educational attainment	1=Less than 9th grade to 9=graduate or professional degree		5.87 (2.03)
▪ Mother's expectations for student attainment	1=9th grade to 6=post-graduate studies		5.40 (1.08)
▪ Frequency of college communication (advanced courses, college admission tests, careers, finances)	4-12, sum of 4 items 1=never, 2=one time, 3=two or more times		9.07 (2.29)
▪ Number of perceived barriers to college (negative family attitudes, not fitting in, lack of support from professors, not sufficiently prepared academically, lack of study skills, lack of confidence, lack of support from friends, need to work during studies, lack of mentors/models, lack of financial support)	0-10, sum of 10 items Each item scored 0=no, 1=yes		2.59 (2.41)
Family STEM support			
▪ Parents interested in student pursuing STEM	1=not at all interested to 5=very interested		3.90 (1.39)
▪ STEM background in family (at least one member, from parent/guardian, grandparent, sibling, aunt/uncle, cousin)	0=no, 1=yes	Yes (69%)	
Engineering interest and expectations			
▪ Interest in pursuing engineering studies	1=not at all interested to 5=very interested		3.52 (1.47)
▪ Expected educational attainment	1=9th grade to 6=post-graduate studies		5.30 (1.14)

Table 1. Frequencies, means, and standard deviations for variables used in the analyses (n=193)

questionnaires at the first club meeting. The sample for this study includes 226 club participants who completed the questionnaire in Fall 2010. The majority of participants were male students (61%), and grades from 7 through 12 were represented, with the largest proportion of participants being in 7th grade (31%). Overall response rate was acceptable at 71% (226 of 320 total club members); with the response rate for middle school students (63%) significantly lower than that of high school students (80%).

Instrumentation

This study utilizes assessment data collected from club participants at the first club meeting in Fall 2010. The assessment questionnaire, written in Spanish, focused on attitude toward engineering; course-taking and enrichment activities; and interest in and knowledge of science and engineering in general, and nanotechnology and materials science in particular. Additionally, the questionnaire included measures of attainment expectations and interest in completing STEM career studies; perceived parent expectations; family communication about college; perceived barriers to enrolling in college; and members of extended family with STEM degree. The items on attitude toward engineering were adapted from the Pittsburgh Freshman Engineering Attitude Survey (PFEAS) (Besterfield-Sacre, Altman, & Shuman, 1998), while the items on perceived barriers to college were adapted from the Perceptions of Educational Barriers scale (McWhirter, 1997).

Table 1 provides details on item wording (translated to English from Spanish), scoring, and descriptive statistics for variables from the questionnaire that were involved in the data analyses. Three categories of independent variables were estimated, following the conceptual framework: person factors (gender, grade level), cognitive factors (perceived value of studying engineering, preferring math and science courses, engineering self-efficacy), and two sets of contextual factors: family college-going culture (mother's attainment, mother's expectation for student attainment, college communication, perceived barriers to college), and family STEM support (parents' interest in STEM career for student, STEM graduate in family).

For the ordinary least squares (OLS) regression models derived from the data, it was assumed that the Likert-type and ordinal responses for interest in engineering and educational attainment expectations represented continuous numerical values.

In the study we sought construct validity evidence for the scores by examining expected relationships between the independent and dependent variables used in the regression models. Social Cognitive Career Theory (SCCT) would predict positive relationships between cognitive and contextual factors (independent variables) and career goals and interests (dependent variables). Two variables had moderately positive and statistically significant ($p<0.001$) correlations with student's interest in studying engineering; engineering self-efficacy ($r=0.37$) and parent interest in a STEM career for the student ($r=0.43$). Family contextual factors were positively related to student's expected educational attainment, including frequency of communication about college ($r=0.35$), mother's educational attainment ($r=0.60$) and parent interest in STEM career for the student ($r=0.37$), all at significance levels of $p<0.001$. Overall, the small to moderate correlations of the independent variables with the dependent variables is likely due in part to the nature of the measures, several of which were single items and/or dichotomous measures. This is a noted area of limitation for the study.

Variables	Interest in engineering (n=193)	Expected attainment (n=196)
Person factors		
Gender (female)	-0.20**	0.13*
Grade level	-0.03	0.10
Cognitive factors		
Studying engineering is worth the effort (agree)	0.16*	0.14**
Like science and math courses more (agree)	0.03	0.12*
Engineering self-efficacy	0.13	-0.04
Family college-going culture		
Mother's educational attainment	0.14*	0.05
Mother's expectations for student attainment	0.03	0.46***
Frequency of college communication	0.05	0.17**
Perceived barriers to college	-0.05	-0.11*
Family STEM support		
Parents interested in student pursuing STEM	0.31***	0.22***
STEM background in family (yes)	-0.06	0.04
R^2	0.27***	0.51***

**p<0.05, **p<0.01, ***p<0.001*

Data Collection and Analyses

The questionnaire was administered by the UPRM professor liaison during the first club meeting at each school in Fall 2010, between August and October 2010. Students were told that their participation was voluntary and that the questionnaire would be used for project assessment purposes. No incentives for participation were offered or provided. The study's authors completed an Institutional Review Board (IRB) application to request access to and use of the questionnaire data for purposes of this study, and this request was granted. No personally identifying information was provided to the authors.

Subsequent statistical analyses were conducted including descriptive statistics, correlation, and multiple regression. Cases with missing data on the variables of interest were not included in the analyses (listwise deletion; n=193). Hierarchical ordinary least squares (OLS) multiple regression models were estimated for interest in engineering and expected educational attainment. The independent variables were entered in four blocks, similar to the approach used by Byars-Winston, Howard, and Estrada (2008), to estimate the contribution of person factors, cognitive factors, and two sets of contextual factors in predicting engineering interest and educational attainment expectations. We evaluated the overall coefficient of determination (R^2) as well as the standardized regression coefficients (β) for each analysis. All statistical tests were evaluated at $\alpha=0.05$.

Findings

Prediction of Interest in Pursuing Engineering Studies

Results of the regression models for interest in pursuing engineering are shown in Table 2. Person factors (Model 1) predicted a small amount of variance in interest ($R^2=0.05$, $p<0.01$); specifically, lowered interest was linked to female students. When adding cognitive factors to the regression (Model 2), the predictive ability improved significantly ($R^2=0.19$, $p<0.001$), with value of studying engineering and engineering self-efficacy as positive predictors. In the third model, the inclusion of family college-going factors did not improve the explanatory power of the model, and none of the family college-going factors was a significant predictor.

In the fourth and final model comprising all hypothesized factors, including the addition of family STEM support, the total variance explained improved significantly to $R^2=0.27$ ($p<0.001$). The final set of significant predictors for interest in studying engineering included four factors; being female ($\beta=-0.20$, $p<0.01$), perceived value of studying engineering ($\beta=0.16$, $p<0.05$), mother's educational attainment ($\beta=0.14$, $p<0.05$), and parent interest in STEM career for student ($\beta=0.31$, $p<.001$).

Prediction of Expected Educational Attainment

Person factors (Model 1); grade level and being female; predicted a limited amount of variance in expected attainment (R^2=0.07, $p<0.001$), and both were significant positive predictors. In the second model including cognitive factors, both person factors remained statistically significant, and all three of the cognitive factors were significant predictors. The change in explained variance was also statistically significant, increasing to R^2=0.16, $p<0.001$).

With the addition of family college-going culture factors in the third model, the explained variance increased significantly, jumping 30 points to R^2=0.47 ($p<0.001$); however, both personal factors and one cognitive factor (engineering self-efficacy) lost statistical significance. Perceived value of studying engineering and preferring math and science courses remained significant predictors. Among the college-going variables, mother's expectation for attainment was the strongest factor. Frequency of academic communication with parents and perceived barriers to college were also statistically significant predictors.

With family STEM factors added in the final model, R^2 increased significantly again, to 0.51 ($p<0.001$). The final set of significant predictors for expected attainment included seven factors. In order of standardized coefficient values, they were mother's expectation for attainment (β =0.46, $p<0.001$), parents' interest in STEM career for the student (β =0.22, $p<0.001$), frequency of academic communication with parents (β=0.17, $p<0.01$), perceived value of studying engineering (β =0.14, $p<0.01$), being female (β =0.13, $p<0.01$), preference for math and science courses (β =0.12, $p<0.05$), and perceived barriers to college (β =-0.11, $p<0.05$).

Discussion

Person, cognitive, and family contextual factors explain a substantive and statistically significant proportion of variance in both interest in pursuing engineering studies and attainment expectations among the underserved engineering club participants in our sample. The results support previous research using social cognitive career theory (SCCT) to understand educational aspirations (Ojeda & Flores, 2008) and interests and goal intentions in math and science (Garriott, Flores, & Martens, 2013; Navarro, Flores, & Worthington, 2007). While the proposed model based on SCCT predicted a much greater proportion of variance in expected attainment (51%) than in engineering interest (27%), the results are encouraging to indicate the relevance of a social cognitive lens to understand the development of career interests in engineering among underrepresented youth.

Gender emerged as a contrasting influence for educational aspirations and engineering career interests. While the middle and high school Latinas in the sample indicated higher educational aspirations than their male peers, they indicated lower interest in studying engineering as a career, which is in line with national findings related to girls' plans to study STEM (National Science Foundation, 2008; 2009). At UPRM, the higher education partner in this study, some undergraduate engineering majors have majority female students; chemical engineering (~60%) and industrial engineering (~50%); while other majors show more typical levels of female enrollment. However, the proportion of women in graduate engineering programs at UPRM is similar to other institutions in the United States. Given this gender difference, future studies should consider examining SCCT models separately for male and female students, to understand whether different personal, cognitive, and contextual factors play a role in the development of engineering interest based on gender.

Curiously, age (grade level) was a positive predictor for expected educational attainment, but not for interest in an engineering career. Some previous research suggested that interest in STEM and engineering may decrease as students progress from elementary through middle and high school and that the decline is more pronounced for girls (e.g., Sadler, Sonnert, Hazari, & Tai, 2012; Sandrin & Borror, 2013). Science interest in middle and high school is linked to STEM degree completion (e.g., Maltese & Tai, 2011) and it may be particularly important for girls to have school-related activities to stimulate that interest (Maltese & Tai, 2010). As more public schools in the United States formally incorporate engineering curricula, it will be important to examine how exposure to engineering at earlier ages may help students sustain interest over time, resulting in higher numbers of students enrolling in engineering majors.

Cognitive factors were significant predictors of both outcomes; however, liking math and science more than other courses was only significant for expected educational attainment (not engineering interest). The findings partially support previous work on the importance of self-efficacy in the prediction of interest and goal intentions for math and science for youth (Garriott, Flores, & Martens, 2013; Navarro, Flores, & Worthington, 2007) in that liking math and science was linked to higher expected attainment. However, we did not find any relationship between our measure of engineering self-efficacy and engineering interest. Future research should incorporate and adapt validated measures of engineering self-efficacy (Concannon & Barrow, 2009; 2012) to understand the nature of this specific type of self-efficacy among middle and high school students, and how it contributes to future enrollment in engineering majors.

Finally, family contextual factors were key in the prediction of both expected attainment and engineering interest. Young people's perceptions of their parents' expectations, frequency of communication about college, and perceived emphasis on a STEM career (in addition to parental educational attainment) represented the strongest predictive factors in the models. Previous studies have found that potential first-generation college students tend to have lower self-efficacy and perceive a greater number of barriers to attending college (Gibbons & Borders, 2010). Our results support the notion that while parents' own attainment may be important, the development of college-going aspirations can be fostered through communication of expectations and family support and advice (e.g., Lopez & Vazquez, 2006; Yosso, 2005). In contrast to other research using SCCT that links parental occupation to science interest and career trajectories (e.g., Chakraverty & Tai, 2013), having a family member in a STEM occupation did not predict engineering interest among the students in our sample.

Summary

While a considerable amount of research has been conducted on educational aspirations and expectations related to engineering, this study addresses a gap by using an alternate conceptual framework – social-cognitive career theory – and by focusing on an understudied population with limited college-going - low-income public middle and high school students in Puerto Rico. The results indicating the influence of gender, perceived value of studying engineering, and family communication and expectations have implications for school and program personnel, including teachers, counselors, administrators, and higher education providers.

Perceived value of engineering to society is central. Viewing engineering study as "worth the effort" was a significant predictor of engineering interest and expected attainment among the students in our sample, and nearly all students (96%) agreed with this statement. We cannot discount the fact that our study participants were already enrolled in an engineering club, thus, likely had higher levels of interest and higher levels of parent emphasis on STEM than their peers at the same schools. Teachers and counselors can help foster an appreciation of engineering as a valuable pursuit by designing curricular, counseling, and afterschool activities that emphasize not only the technical aspects to help students understand the nature of engineering, but also activities to convey the value of engineering for society.

STEM education as a family affair. For the students in our sample, family communication and expectations about college and STEM careers were strongly related to an interest in an engineering career and expected educational attainment. Afterschool clubs and outreach activities should include opportunities for parent and family involvement to attract underrepresented groups to engineering. Just as it is important for students to see engineering as valuable, parents also need to realize the value and use of engineering in society. For example, the

Committee for Hispanic Children and Families (2015) in Bronx, New York offers afterschool workshops for parents in conjunction with a project-based STEM curriculum for elementary and middle school students and their families. Activities that involve parents and families can go a lot further to changing societal views and valuing of engineering, over activities that only involve children and youth.

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