Increasing Diverse Students' Persistence in Engineering: A Social Cognitive Perspective

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***Abstract*— This presentation adds to the social cognitive career theory (SCCT)[1, 2] research in engineering[3-10] to understand factors associated with Latino/a engineering students' engineering self-efficacy and engineering outcome expectations. We highlight findings from one empirical study about the associations among perceived support in engineering, perceived barriers in engineering, engineering-related learning experiences (i.e., performance accomplishments, vicarious learning, verbal encouragement, emotional arousal), and two social cognitive variables: engineering-related self-efficacy and engineering-related outcome expectations. A path analysis was performed with a sample of 655 Latino/a (255 women and 400 men) engineering students attending 11 universities across the U.S. who completed an online survey. Findings indicated that engineering self-efficacy was associated with perceived supports and all four learning experiences. Engineering outcome expectations were explained by engineering self-efficacy, perceived supports, verbal encouragement and low emotional arousal. Perceived barriers had no significant effects on either self-efficacy or outcome expectations. Implications of the findings are discussed in relation to classroom practices aimed to enhance students' engineering-related self-efficacy and outcome expectations.**

Keywords—Social Cognitive Career Theory; Latinos(as); self-efficacy

I. Introduction

The development of a diverse engineering workforce is a key mission of the U.S. society and within engineering education. This is in light of data that we are moving toward a society in which people of color will comprise a majority of U.S. population, and that by 2020, White children will be in the minority [11]. At 17%, Latinos/as are the largest racial/ethnic group after Whites and are one of fastest growing groups today [12]. In less than ten years, they are expected to comprise one-third of the U.S. school-aged population [13]. Latinos/as are sorely underrepresented in engineering and little progress has been made in recent years to increase their representation in engineering. Only a small proportion of Latino/as major in engineering (7.9% Latinos and 2.2% Latinas; [14]) and receive an engineering degree (6.2% Latinos, 1.8% Latinas; [14, 15]). Thus, efforts can be made within engineering education to broaden the participation of Latinas/os in engineering.

Vocational psychology theories provide useful frameworks for explaining the career decision making process and how people accomplish career-related goals. Social Cognitive Career Theory (SCCT; [1, 2]) has been a powerful theoretical framework to predict students' academic satisfaction and persistence intentions. One of the reasons that SCCT has been so widely used is its focus on social cognitive variables which are changeable to intervention [16, 17]. This paper uses SCCT to understand the effects of environmental (i.e., perceived supports, perceived barriers) and learning experiences (i.e., performance accomplishments, vicarious learning, verbal encouragement, and emotional arousal) on the development of both engineering related self-efficacy beliefs and outcome expectations among a sample of Latino/a engineering students [1, 2].

SCCT has been used to understand the development of career interests, career choices, and performance outcomes among engineering students in prior research [3-10]. Embedded within SCCT is Bandura's self-efficacy theory, which hypothesizes that self-efficacy beliefs (i.e., confidence in one's ability to successfully perform career-related tasks) and outcome expectations (i.e., anticipated outcomes of a particular behavior) develop from four sources or learning experiences: prior performance accomplishments, vicarious learning, verbal encouragement, and low levels of emotional arousal [18, 19]. Differential exposure to or access to these four sources may be influenced by personal demographics and life circumstances, leading to discrepancies in levels of self-efficacy and outcome expectations between groups, and ultimately, differences in career interests, goals, and performance [1]. Self-efficacy and outcome expectations are two key social cognitive variables that are hypothesized to shape interests, goals, satisfaction and persistence [1, 20], and relations among these key social cognitive constructs and career outcomes have been largely supported in prior research with engineering students [3-6, 9, 10, 21, 22].

In addition to the hypothesized relations between learning experiences and both self-efficacy and outcome expectations, SCCT studies have provided empirical evidence for a direct link from perceived supports to engineering self-efficacy [4-6, 9, 10, 23] and outcome expectations [5, 6, 23], suggesting that students who perceive strong support from others for pursuing engineering activities are likely to report high levels of confidence for engineering activities and to anticipate positive results for engaging in engineering activities. Prior research has also found associations between perceived barriers and self-efficacy [4, 10, 22] and outcome expectations [22, 23], indicating that high perceived barriers in engineering are associated with lower levels of self-efficacy and outcome expectations. Thus, according to SCCT and based on prior research, differences in one's educational environment (i.e., learning experiences) and exposure to resources (i.e., perceived supports) and obstacles (i.e., perceived barriers) may contribute to discrepancies in the social cognitions that influence career choices. These differences in levels of self-efficacy and outcome expectations may, in part, explain the disparities present in engineering.

In spite of the importance of self-efficacy and outcome expectations in the SCCT model and to educational and career outcomes, few studies have tested the learning experiences portion of the model that links learning experiences to the development of self-efficacy beliefs and outcome expectations for engineers, particularly for women and minorities in engineering. This research is needed to inform training and instructional practice that are salient in the development of these social cognitions. One prior study examined the effects of engineering-related learning experiences on engineering self-efficacy and outcome expectations among a sample of engineering students [24]. One domain of engineering-related activities included working with ideas, abstract concepts, and math and science activities (Investigative) and another domain included working with things, or manual activities (Realistic). Results indicated that Investigative self-efficacy was predicted by 3 of the 4 learning experiences (i.e., vicarious learning, verbal encouragement, and emotional arousal), while Realistic self-efficacy was only predicted by low emotional arousal. On the other hand, Realistic outcome expectations were predicted by all four learning experiences, but none of the learning experiences had a significant effect on Investigative outcome expectations. Self-efficacy was not associated with outcome expectations for either model. Finally, no differences in the temporal relations among the variables were found across gender or racial groups (Latino/a vs. White). Autoregressive effects (effects of the same variable across time) revealed that White students were verbally reinforced at stronger rates than Latino/a students and that White students' Investigative self-efficacy improved at a faster rate than that of their Latino/a peers over time. This study provided important information for guiding engineering educators in developing classroom and lab practices that can enhance Latino/a students' engineering-related self-efficacy and outcome expectations. The current study adds to this literature by assessing engineering-specific variables and by sampling Latino/a engineering students at multiple institutions.

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To summarize, due to the underrepresentation of Latino/as in engineering, the current study investigates if engineering learning experiences differentially impact engineering self-efficacy and outcome expectations. Further, we examine the direct effects of perceived engineering supports and perceived engineering barriers on students' engineering self-efficacy and outcome expectations. See Fig. 1 for the model that was tested in the current study.

II. Method

A. Participants

Six hundred fifty-five engineering students (n=255 women; n=400 men) who identified as Latino/as were used in the current study. Of these participants, 205 (31.3%) identified as first generation, 323 (49.3%) as second generation, 45 (6.9%) as third generation, 47 (7.2%) as fourth generation, and 35 (5.3%) as fifth generation. One hundred thirty-one (20%) were in their first year of college, 146 (22.3%) were in their second year, 195 (29.8%) were in their third year, 177 (27%) were in their fourth year, and 6 (.9%) reported "other." The mean age of the participants was 21.28 years (SD = 3.25 years; range = 18-48). Of the engineering specialties represented, 154 (23.5%) were in mechanical, 94 (14.4%) were in electrical, 112 (17.1%) were in computer, 112 (17.1%) were in civil, 33 (5%) were in chemical, 21 (3.2%) were in aerospace, 39 (6%) were in industrial, 54 (8.2%) were in biomedical, 5 (.08) were in architectural, 6 (.9%) were in manufacturing, and 35 (5 %) were in "other."

B. Procedure and Instruments

Participants were recruited from engineering colleges at 11 U.S. universities. Most were public institutions and they ranged in size from engineering enrollments of 803 – 5724 students. Five were classified as Predominantly White Institutions and six were Hispanic-serving Institutions. In Spring 2015, emails were sent via the college's listserv and flyers were distributed in key undergraduate engineering courses and student organizations announcing the study and inviting students to complete an online survey.

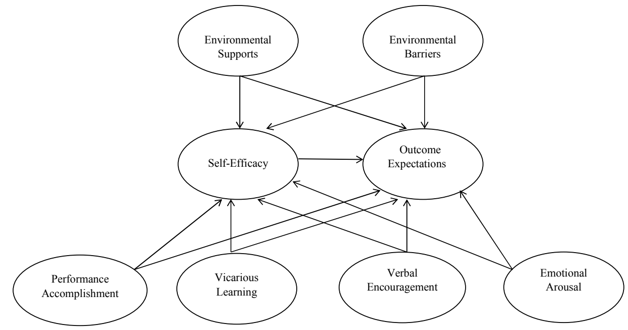

Fig. 1. Hypothetical model proposed to assess the relationships among supports, barriers, self-efficacy, and outcome expectations.

The online survey included measures to assess engineering learning experiences, engineering self-efficacy, engineering outcome expectations, engineering supports, engineering barriers, and a demographic form. All of the measures demonstrated good reliability and validity estimates. The study was approved by the Institutional Review Board, and participants received a $20 gift card to an online retail store for their involvement in the study. The template is used to format your paper and style the text.

III. Results

A. Preliminary Analysis

The data were examined for accuracy of data entry, missing values, and assumptions of multivariate analyses [25]. We began with a data set of 1719 cases. In terms of case deletion, 318 cases were removed because they had missing data of more than 10% on each of our measured variables. After that, a total of 192 cases were detected to be univariate outliers on the measured variables, and an additional 22 cases were deleted for multivariate outliers, leaving 1187 cases. Among these, 655 students identified as Latino/s, 511 students identified as White, 19 students identified as multiracial or multiethnic, and 2 identified as "other." Because the current study aims to examine sources of Latino/s students' self-efficacy and outcome expectations in engineering, only those participants who identified as Latino/as (N=655) were used for the primary data analysis. See Table 1 for the descriptive statistics, alphas, and bivariate correlations among the study's variables.

B. Primary Analysis

A structural equation model analysis was performed using AMOS 21 statistical package. Overall model fit was determined by using a variety of goodness of fit measures. The first measure of model fit is the chi-square test. If a model provides adequate fit, a small chi-square value and a nonsignificant p-value are expected. Other fit indexes are examined to test adequate fit because the chi-square statistic is sensitive to sample size and model misspecification [26]. Our study examined root mean square error approximation (RMSEA), Tucker-Lewis index (TLI), and comparative fit index (CFI) and the chi-square text divided by its degrees-of-freedom (χ^2/df) to assess our models. An adequate fit to the data is reported when χ^2/df $\leqslant$ 3, CFI and TLI values $\geqslant$ .90 and RMSEA $\leqslant$ .08. When χ^2/df $\leqslant$ 3, CFI, and TLI values $\geqslant$ .95 and RMSEA $\leqslant$ .06, the data represents a very close fit to the model [27, 28]. According to these guidelines, the data for our sample was a good fit to the hypothesized model [(χ^2/df = 2.44; CFI = .89; TLI= .89; RMSEA = .05 with 90% confidence interval = 0.045, 0.049)]. Results suggested that all paths in the model were significant except for four paths from perceived barriers to engineering self-efficacy, perceived barriers to engineering outcome expectations, engineering performance accomplishment to engineering outcome expectations, and engineering vicarious learning to engineering outcome expectations. The variables explained 38% of the variance in engineering self-efficacy and 28% of the variance in engineering outcome expectations. See Table I and Fig. 2 for the standardized path values associated with the model.

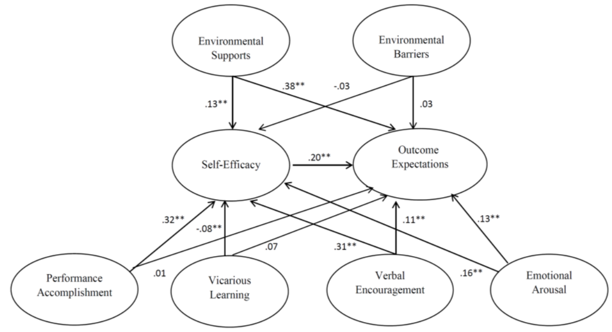

Fig. 2. Results of testing using the hypothesized model show several factors impact both self-efficacy and outcome expectations at a significance level of $p < 0.05$, as represented by **.

IV. Discussion

Our study's aim was to assess the effects of Bandura's four learning experiences (i.e., performance accomplishments, vicarious learning, verbal encouragement, emotional arousal) and two environmental variables (i.e., perceived supports, perceived barriers) on self-efficacy and outcome expectations in the engineering domain [18, 19]. The present findings supported the SCCT-based model to explain the development of engineering self-efficacy and engineering outcome expectations among a sample of Latino/a engineering students. Specifically, performance accomplishments, verbal encouragement, vicarious learning, emotional arousal, and perceived supports had significant effects on engineering self-efficacy. In addition, self-efficacy, perceived supports, verbal encouragement, and emotional arousal had significant effects on engineering outcome expectations.

Consistent with Bandura's theory, prior performance accomplishments in engineering activities had a positive effect on engineering self-efficacy beliefs [18, 19].

TABLE I. Descriptive statistics and correlations among the variables

Variable	***Mean***	***SD***	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Engineering PA	4.81	.82	-						
Engineering VL	4.51	1.02	.28**	-					
Engineering VP	4.18	.86	.50**	.30**	-				
Engineering PhA	3.81	1.05	.19**	.02	.20**	-			
Engineering SE	7.15	1.56	.44**	.18**	.50**	.29**	-		
Engineering OE	7.62	1.12	.27**	.24**	.37**	.20**	.40**	-	
Support	3.95	.67	.30**	.35**	.35**	.13**	.33**	.46**	-
Barrier	2.23	1.04	.003	-.07*	.05	-.33**	-.12**	-08	-.11**

Note. Engineering PA = Engineering Performance Accomplishments; Engineering VL = Engineering Vicarious Learning; Engineering VP = Engineering Verbal Persuasion; Engineering PhA = Engineering Physiological Arousal; ** $p < .01$. Number refers to each variable's correlation.

Among the variables in the model, performance accomplishments had the largest effect on self-efficacy, suggesting that experiencing success and feelings of accomplishment in engineering tasks plays a critical role in shaping engineering self-efficacy. Engineering educators should provide ample opportunities for first year students to build at least minimal levels of self-efficacy through successful performance accomplishments.

The most rigorous courses for engineering students may be examined for ways to alter the learning experience so that students can grasp the material more easily. Instructors may start with very basic systems and examples in these courses, allowing students to work in teams to solve those questions, and as the term progresses, move towards increasingly complex questions reflecting higher levels of learning. This is especially important for the most challenging courses offered in the first year, when students are less likely to have had multiple opportunities for successful academic experiences that might balance out "failures." Thus, breaking down challenging material that is taught in the first year and changing the sequencing of the "weed-out" classes so that they are offered in later years after students have some successful experiences under their belt may help in efforts to retain Latino/a students.

This finding also has important implications for academic advising. Academic advisors can work with students to carefully plan coursework in the first year or during later semesters when students will be taking the most challenging courses. Specifically, students should be advised to balance their course load in their first two semesters so that they are not taking more than two challenging courses at the same time. The most difficult courses can be taken with other required general education courses outside of engineering so that students can focus on mastering the most challenging coursework. Finally, to provide Latino/a engineering students with the best chances for succeeding in classes, engineering faculty can consider providing resources that are available on campus to help students succeed academically. For example, at the beginning of each term, faculty may provide a list of links to the available resources on campus, such as academic success centers, one-on-one tutoring opportunities (often through the department, college, and university), small group study sessions, professional societies, etc. Faculty also can share the practices of students who have been successful in their particular classes.

Contrary to our hypothesis, vicarious learning was negatively related to engineering self-efficacy. However, this finding is consistent with a previous study performed with Latino/a engineering students that reported a negative effect between vicarious learning and outcome expectations [24]. It is possible that family members have had negative experiences in engineering careers and that exposure to these experiences (e.g., hearing about them at home, observing the negative effects on family members' well-being) has shaped students' self-efficacy beliefs in engineering. Alternatively, given Latino/as' low representation in engineering fields, it is also possible that there have been few opportunities for Latino/a students to see others successfully perform engineering-related tasks. Faculty may consider ways that they can bring in Latino/a engineers in the field or advanced Latino/a engineering students into the classroom to give presentations and to serve as positive models for students. These guests can share their successful experiences in the field (including times when they overcame barriers in their career) and address positive uses of an engineering degree. Alternatively, faculty could use Latino/a graders, teaching assistants, learning assistants, coaches, or tutors for the class, if they already plan on including students in those positions. Increasing exposure to Latino/a engineers who have been successful can help to counter the effects of the role models or images that have offered negative feedback about engineering activities. Future research should explore the types and quality of vicarious learning experiences in engineering among Latino/a students.

Similar to Flores et al.'s findings, verbal encouragement was positively related to both self-efficacy and outcome expectations [24]. In our study, verbal encouragement had a moderate effect on self-efficacy and a small effect on outcome expectations. Thus, receiving active, sustained encouragement and support from significant others, including faculty, advisors, peers, teachers, parents and siblings, for participating in engineering activities is a critical source of self-efficacy relative to other sources in shaping Latino/a students' confidence for success in engineering and positive expectations for engaging in engineering activities. Engineering faculty and advisors can find ways to communicate their confidence in Latino/a students' abilities in engineering, to identify Latino/a students' strengths in engineering, and to acknowledge areas in which they are growing and making improvements. Faculty may also reflect on ways that they respond to students' questions and to instances when students' have a wrong answer, as negative or neutral responses may chip away at a students' engineering self-efficacy. In light of previous findings, which found that White engineering students received more verbal encouragement for engineering-related tasks over time than Latino/a students, it is important that faculty are actively engaged in encouraging Latino/a students and that they consistently do it across students' training [24]. In short, positive encouragement plays an important role in shaping Latino/a students' self-efficacy and outcome expectations in engineering.

Consistent with prior research, low emotional arousal had a small, but positive effect on engineering self-efficacy and outcome expectations [24]. Helping Latino/a students to identify common stressors that they may encounter as engineering students and providing them with techniques to deal with the stress is another intervention that can boost their self-efficacy and outcome expectations in engineering activities. Mental health professionals that are employed at college/university counseling centers and student health clinics can be invited to provide workshops to engineering student cohorts to address developmental appropriate stressors (i.e., homesickness and transitioning to college for first year students; job search for fourth and fifth year students). These may be done during the common freshman- and senior-level seminar classes. Repeating these workshops each year can assist students in managing academic stressors and reducing anxiety. In addition, it is possible that heightened arousal among students of color may be related to stereotype threat [29], or the stress experienced when students are at risk of conforming to academic stereotypes for members of their group. Faculty members should be aware of the negative effects of stereotype threat on Latino/a students and actively counter these stereotypes by communicating confidence in Latino/a students' abilities to succeed in engineering.

Perceived social support for engineering also had positive effects on Latino/a students' self-efficacy and outcome expectations. Students who perceived high levels of support from important people in their lives were more likely to report high levels of engineering self-efficacy and to expect positive rewards for pursing engineering. Efforts to enhance support for Latino/a engineering students should consider types of support that may be especially relevant for these students, including receiving mentoring and guidance in the profession from both faculty and advanced students, assistance with financial aid and decision-making, networking with other Latino/a engineering students and engineers both within the university and beyond, academic tutoring, and career decision-making. Faculty can play an important role in encouraging Latino/a engineering students to develop their support networks by sharing with students information about professional societies where students can build their professional networks. Faculty can extend invitations to students to stop by to visit with them during office hours. Making oneself available to students outside of class to discuss both their academic experiences as well as to get to know them as individuals is an especially effective way in which faculty can demonstrate support for Latino/a students. In short, our findings suggest that perceived support is a solid predictor of positive consequences that Latino/a students believe they are going to deal with if they pursue engineering.

Our findings supported the hypothesized link between self-efficacy beliefs and outcome expectations. Thus, among our sample of engineering students, high perceived confidence in one's skills for engineering tasks is associated with perceived positive outcomes for engaging in engineering activities. These findings provide support for self-efficacy based interventions as a path toward enhancing outcome expectancies associated with engineering. Strengthening both self-efficacy beliefs and positive outcome expectations among engineering students, particularly Latino/a students, may contribute to a department's or college's efforts in retaining these students in engineering and increasing graduation rates of Latino/as with engineering degrees.

We want to highlight the non-significant effect of perceived barriers on both self-efficacy and outcome expectations. It is possible that the measure that we used to assess engineering barriers does not tap into the barriers that are relevant to Latino/a students. It is still too early to rule these out as a relevant factor without additional research. Future qualitative research should explore the barriers that Latino/a students encounter in engineering to determine if existing instruments are adequately capturing their experiences.

To summarize, across both social cognitive variables, instructional practices and psychoeducational efforts to increase social supports, enhance positive verbal feedback, and provide skills for managing negative feelings that are associated with engineering academic tasks were each significant predictors of both engineering self-efficacy and outcome expectations. Performance accomplishments and vicarious learning were also predictive of engineering self-efficacy. Based on the findings of our study and the relative strength of the different predictors, we recommend that engineering educators who want to enhance Latino/a students' self-efficacy, focus on increasing opportunities for these students to engage in engineering-related tasks (with some level of accomplishment) and to monitoring the verbal encouragement provided to these students. On the other hand, engineering educators who want to enhance Latino/a students' positive outcome expectations related to engineering should focus on developing supports across multiple sources for these students. Engineering departments may also consider providing professional development opportunities for faculty to introduce them to challenges that Latino/a students face in engineering. Professional development opportunities for faculty and teaching assistants that addresses how to implement these suggestions in the classroom or within training programs is also suggested. Future research may study the effectiveness of these professional development trainings in better preparing faculty and teaching assistants to work with Latino/a students. Many of the possible interventions presented here for each scenario are already considered "best practice" in engineering education; it is important to remember that these practices should theoretically have a positive impact on all students in the classroom to which the practices are applied. However, we suggest that, of the wide range of best practices available, the examples given will likely have the most impact on the long-term retention of Latino/a students.

The current study is one of the few SCCT studies that has examined the effects of learning experiences on self-efficacy and outcome expectations. In addition, we included two environmental variables, perceived supports and perceived barriers, to understand their unique contributions to shaping these social cognitive constructs among engineering students, over and above the effects of the four learning experiences. This study contributes to the SCCT literature by testing this model with a large sample of Latino/a engineering students who were drawn from 11 different universities across the U.S. The current study also improves upon prior research by using a learning experience measure that was specific to engineering coursework, allowing us to understand the effects of academic activities that are common in the training of engineers to engineering-specific self-efficacy and outcome expectations.

As with all studies, our study also has limitations including the use of cross-sectional data which limits the understanding of the temporal effects among the variables in the model. In addition, while the use of an engineering learning experience measure is a strength, this measure is still in development and more research is needed to evaluate the reliability and validity of scale scores with other samples. Future research should explore gender differences in the model across Latino and Latina samples to assess if gendered experiences in engineering may moderate the relations among the SCCT variables that we tested. In addition, the model should be explored with other groups of engineering students to understand if there are any differential effects of the learning experiences and environmental variables across racial groups.

To conclude, our findings provided support for the SCCT model in which engineering learning experiences and contextual variables explain both engineering self-efficacy and outcome expectations, two central social cognitive factors that have been shown to influence the development of career interests, goals, and performance behaviors. We highlighted some promising strategies for individual faculty, classroom strategies, and program/department activities to build Latino/a students' engineering self-efficacy and to increase positive engineering outcome expectation.

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