Measuring Self-Efficacy in Diverse First-Year Engineering Students Exposed to Entrepreneurial Minded Learning

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***Abstract*—This Innovative Practice Category full paper presents research in which Entrepreneurial Minded Learning (EML) was implemented in introductory engineering classes, as an intervention, to study how EML influences self-efficacy between students of Hispanic and non-Hispanic ethnicities at a Hispanic Serving Institution. The EML tenet is to include the "three C's" in project-based learning: curiosity, connections, and creating value. A key question is whether EML not only influences student learning but also the students' confidence in being successful engineers. Much work has been done studying how EML affects learning, yet few studies look into the effect of the mindset on self-efficacy. Moreover, self-efficacy is known to differ depending on a person's race and ethnicity. We studied three groups: (i) a cohort not exposed to EML; (ii) a cohort exposed to EML design projects lightly guided by a student-mentor; (iii) a cohort exposed to EML design projects heavily guided by faculty and a graduate student. We performed pre- and post-surveys to evaluate how strongly students identify as engineers when exposed (or not) to EML. We find that participation in an introductory engineering course itself may have more influence on students' engineering self-efficacy than the specific level of EML within the course.**

I. Introduction

Self-efficacy is the idea that engagement in a process is affected by a mindset about personal capabilities [1]. The basic definition of self-efficacy, a component of social cognitive theory, can be applied to any process [2], and it is often a key component of discipline-based educational research. When external factors that influence personal perceptions are looked at closely, new frameworks on the effectiveness of teaching are developed. Accordingly, many models have been established to predict ways in which teaching affects self-efficacy in learners as well as how self-efficacy influences motivation to grasp material and persevere in the classroom. The science of self-efficacy has fostered an understanding on how students "learn how to learn" and the influence of metacognition in education.

In the case of engineering education within colleges and universities, the theory of self-efficacy focuses on attitudes and self-beliefs toward the ability to practice as a professional engineer [3]. Within engineering, it is widely noted that T-shaped professional skills are important, in that engineers need a depth of technical knowledge crossed with the ability to be effectual, critical, systematic, multidimensional, and cross-disciplinary thinkers. Acquiring such cognitive traits is a process that in and of itself is directly affected by self-efficacy. Meaning, when students believe they are able to be effectual thinkers they develop the "thinker traits," which are important for thriving in a global economy that is changing owing to de-industrialization and technological advancements [4]–[7]. This is important because the engineering workforce has evolved away from manufacturing jobs to employment opportunities that require small and highly focused multidisciplinary teams. An engineer is continually being challenged to develop solutions to problems which are multidimensional and cross-disciplinary (e.g., changing consumer demands, increased productivity, improvements in agriculture and industry, and outsourcing of industry to low-income nations) [7]. Therefore, self-efficacy plays a large role in how flexible an engineer is to constant change, complexity, and uncertainty [8].

One type of self-efficacy that is an important assessment tool for the T-shaped skills achieved by engineering students is innovation self-efficacy (ISE). ISE is the cognition of an individual's ability to succeed at tasks associated with innovation. A strong ISE has been recognized as valuable for engineering students, who must become proficient not only in production and design but also in the ability to create value in new economies [9], [10]. If engineers drive economic growth and create new markets, existing organizations, start-ups, and manufacturing companies significantly benefit. In other words, large companies are revitalized when they acquire start-ups, are consolidated, merged, or broken into subsidiaries. Therefore engineers with high ISE help enhance the aforementioned industrial conditions and are naturally innovative, visionary, and opportunity seeking [4]. Research to test the impact of ISE in engineering education has ranged from intervention-like studies to simple surveys and observations [11], [12].

Innovation is closely related to entrepreneurship skills, thus entrepreneurial self-efficacy (ESE), has been recognized as a valuable trait for students throughout the engineering education literature [10], [13]. ESE overlaps conceptually with ISE because both are mindsets related to personal effectual logic, or entrepreneurial logic [14], [15]. Effectual thinkers have a mindset that centers around idea generation where the focus is on developing several means that can lead to different end goals. Whether coined as ISE or ESE, both are noted as essential for engineering because eventually the engineer worker will be engaged in jobs and situations where uncertainty is expected. Expectedly, a concerted endeavor has been underway to introduce the entrepreneurial mindset into engineering curricula through the entrepreneurial minded learning (EML) initiative [16].

EML has gained substantial traction by U.S. universities where a focus on teaching the entrepreneurial mindset enhances personal effectual logic, or entrepreneurial logic [14]. EML can be contrasted to the traditional approaches to learning which take a causal logic approach, also described as managerial engineering based. With causal thinking, an engineer might focus on one end goal and identify different means simply to find the singular answer [16], whereas EML moves beyond such problem- and project-based learning. EML adopts active learning while infusing outcomes into those activities so as to "understand the motivations and perspectives of others," "discover through inherent curiosity," and "develop a contrarian view of accepted solutions" [16]. EML is described in detail elsewhere, and in general focuses on developing the cognitive aspects of the entrepreneurial mindset using the "three C's", curiosity, connections, and creation of value. Moreover it has been implemented across a wide range of engineering curricula and assessed through community forums and modules that demonstrate effectiveness.

In this contribution we focus on the influence of EML in engineering education and how it influences self-efficacy. Beyond this correlation we also investigate how self-efficacy in engineering manifests depending on unique demographic categories. That is, we focus on differences in self-efficacy between underrepresented Hispanic minority students and non-Hispanic students, because self-efficacy is so closely tied to personal experiences and is known to affect how minority students integrate into the STEM community [17]. In fact, there is a wide body of literature that describes how self-efficacy is different when minority students studying STEM-related disciplines are compared to non-minority students [17], [18]. More than this, intersectionality is known to be a major influencing factor on a student's motivation to persist in engineering [19]–[21], and the connection between self-efficacy and cultural environments impacts long term development of student identity in engineering and the sense of belonging to the engineering community [22]–[25].

Therefore, our paper presents an outlook on engineering education through the lens of EML, self-efficacy, and cultural identity. Our main goal is to measure differences in Hispanic students' attitudes on their ability to practice as an engineer when exposed to EML curricula, and determine if the self-efficacy that we measure is different from non-Hispanic students also engaged in a classroom where EML is emphasized. Our research involved an intervention-like study in which we took students in first-year engineering design classes, a total of three sections, where the demographic breakdown was random, although predominantly minority owing to the typical ethnicity found at our Hispanic serving institution. We developed EML modules that were spiked into various parts of two experimental introductory engineering classes, and using IRB-approved questionnaires we compiled data taken both at the beginning and end of the semester probing self-efficacy. Finally we juxtapose the answers of the Hispanic and non-Hispanic students to seek out differences, if any.

II. Experimental Design

Our approach to studying changes in self-efficacy of first-year engineering students involved a total of three cohorts of students registered in a one-semester introductory engineering course. The design was quasi-experimental due to the use of existing groups rather than random assignment. Below we describe in detail the design specifics, which include pre- and post-surveys, control groups, EML design activities, and a measure of the demographic breakdown of all students.

A. First-Year Introduction to Engineering Course

Entering first-year students enroll in Introduction to Engineering, a 3-credit course that introduces students to engineering design with the intent to increase retention and enhance math and critical thinking skills prior to students matriculating into upper level disciplinary courses. This introductory course provides an introduction to the various engineering disciplines, the engineering approach to problem solving, and the design process. During the semester the students meet twice per week for lecture and once per week for a laboratory, which mainly involves actively building, designing, and prototyping. The laboratory design challenges were team-based (approximately 4 students/team) and tailored to emphasize teamwork, written and oral communication skills, as well as ethical responsibilities. During this semester there were approximately 12 sections of Introduction to Engineering (maximum 32 students in each) of which three sections were chosen for our study.

B. Student Cohorts

From the three sections we designated three cohorts: (i) a first-year cohort not exposed to EML ("Control"), (ii) a first-year cohort exposed to EML design projects lightly guided by a student-mentor ("Light Intervention"), and (iii) a first-year cohort exposed to EML design projects guided by faculty and a graduate student ("Heavy Intervention"). The Light Intervention and Heavy Intervention cohorts were taught by the same course instructor and the Control cohort by a different instructor. Students self-selected their course section to fit their course schedule; as such, demographics of the cohorts may vary slightly. Table I summarizes the total number of students N that consented to participate in our surveys (see Section II-D) and the number of those students N_H who identify as Hispanic within each of the cohorts.

TABLE I
THREE FIRST-YEAR ENGINEERING COHORTS STUDIED IN THIS PROJECT. N IS THE TOTAL NUMBER OF STUDENTS AND N_H IS THE NUMBER OF STUDENTS WHO IDENTIFY AS HISPANIC.

	N	N_H
Control	22	9 (41%)
Light Intervention	26	13 (50%)
Heavy Intervention	26	19 (73%)

C. EML Activities

The EML content, included in the Light Intervention and Heavy Intervention sections, was introduced at separate times across the 16-week semester. A total of three design challenges (described below) were modified to include the "three C's" of entrepreneurial minded learning. Additionally, the instructor of the Light Intervention and Heavy Intervention sections allowed us to guest lecture a couple of times in the class to teach with an active learning approach and EML aspects. The three EML first-year design challenges are described below.

1) House of Cards Design Challenge: The House of Cards: A Customer Focused Design Challenge, can be completed during a single class period, and was developed for EML by Carpenter et al. [26]. This challenge is general enough for first-year engineering students, and sets a baseline for students to learn about EML and the value of teamwork as they apply the mindset. Briefly, The House of Cards challenges teams to construct a tower with a deck of cards under constraints of materials and time. The challenge includes EML components such as ill-defined problem statements with elements that reveal the importance of understanding the customer, motivations and perspectives of others, and creation of value. We used this on the Light Intervention and Heavy Intervention cohorts at the beginning of the semester (after students took the pre-self-efficacy survey). It was directed during a laboratory session and was held in our campus maker space in an effort to induce more creativity simply by the innovative environment. During the Heavy Intervention, we led the challenge and introduced students to the entrepreneurial mindset whereas the Light Intervention group was guided through the challenge by a senior student mentor, and did not receive added information about the mindset. As mentioned previously, a third Control group was not introduced to the EML challenge whatsoever; they took the pre-survey then followed the standard curriculum for the course as prepared by the course instructor.

2) Pulley System Design Challenge: Our second EML-focused project involved a Pulley System Design Challenge. This challenge was turned into an EML format by including a "hook" narrative that students identify with culturally, inclusion of a customer focused challenge, and sparse information to lead students to make connections. The challenge was for students to imagine they were part of a local engineering firm Enchantment Engineering LLC, the same fictional firm used in the House of Cards challenge, developing a pull for farmers to lift bushels of chile (a local crop grown in our southwest region). The assignment included other EML elements including team-work, ill-defined problems, and hidden documents on customer value creation. Similar to the other challenge, a Heavy Intervention group was led by us as EML-focused faculty, and the Light Intervention group was guided by a senior engineering student mentor, who did not emphasize EML as prominently. The Control group did a pulley challenge developed by the standard curriculum and did not include any EML components. This challenge was implemented in one of the laboratory classes mid-way through the semester and students tested their pulley as a team after construction and prepared a written report.

3) Protection of an Occupant Design Challenge: The third activity took place near the end of the semester and was a design challenge that involved construction of a bus shelter. The challenge was turned into an EML project by bringing back the narrative of the Enchantment Engineering firm as well as developing it into a customer oriented story line. Cohorts were challenged to build and test a bus shelter to protect the life of an occupant (egg) that could withstand the impact of a model truck along a ramp (approximately 3 m long at an angle of 45°) with a board (hard stop) at the end of the ramp. Our narrative was focused on student "buy-in," so that they would relate to the challenge socially and culturally while feeling they have a connection and identity with the scenario. That is, we had the students imagine they were constructing the shelter for a bus station at the bottom of a mountain road commonly driven by many of our students. The relevance of this location combined with important safety aspects and customer demands made the challenge into an EML project where connections are needed. Additionally, during the challenge students could iterate on their design and re-build, which taps into the EML element of persistence and learning from failure. Again, the Light Intervention was guided by a senior engineering student mentor and the Heavy Intervention cohorts were guided by us with a stronger emphasis on components of EML. The Control group did not have an EML version of the bus shelter but a generic challenge to make an "egg protector."

D. Surveys

The instruments we used to measure differences in self-efficacy across the cohorts exposed (or not) to EML were surveys administered through our online course management system. Questions were composed that probed student perceptions about their own self-efficacy and identification as an engineer and pre- and post-intervention surveys were administered based on Bandura [1]. Full questions for the pre-intervention survey are shown in Table II and for the post-intervention survey in Table III.

III. RESULTS

All results were compiled at the completion of the first-year engineering course in which the EML activities were performed as well as after all surveys were finalized. We examined closely pre- vs post-survey results and present example data which include selected survey questions which focus on engineering self-efficacy (Section III-A), entrepreneurial mindset (Section III-B), and student perceptions (Section III-C).

TABLE II

PRE-INTERVENTION SURVEY QUESTIONS. QUESTIONS WITH LIKERT-STYLE RESPONSES HAD OPTIONS OF NOT AT ALL, SLIGHTLY, MODERATELY, VERY, AND EXTREMELY.

Question #	Question	Question Type
Q1-pre	Studies have found that first-year engineering students have varying levels of confidence in their ability to succeed as an engineer after they graduate. At this point in your studies, how confident are you in your ability to succeed as an engineer after you graduate?	Likert
Q2-pre	At this point in your studies, how confident are you in your ability to learn the skills required to succeed as an engineer?	Likert
Q3-pre	Studies have found that first-year engineering students have varying levels of interest in creating a value-added product (e.g., writing a phone app, creating the next best widget, or finding a solution to a societal problem) after they graduate. At this point in your studies, how interested are you in participating in such entrepreneurial endeavors after you graduate?	Likert
Q4-pre	At this point in your studies, how confident are you in your ability to create value for others as an engineer after you graduate? Examples of creating value for others as an engineer include: designing new products for customers, seeking efficiency, making innovations in several areas including but not limited to maintenance, security, exploration and defense, biomedicine, and improving community and environmental systems.	Likert
Q5-pre	Engineering students vary in their level of confidence concerning how much or how little they identify as an engineering student. For example, one may be officially recognized as an engineering student but may or may not feel confident that he or she fits traditional expectations of what an engineering student looks like. How confident are you in identifying yourself as an engineering student?	Likert
Q6-pre	Engineering students vary in how much or how little they credit hands-on activities for their interest in becoming an engineer. Examples of hands-on activities include: working on family vehicles, helping out with building things around the house, maintaining farming and hunting equipment, installing computer programs and entertainment systems, school projects or clubs, etc. How much or how little do you credit hands-on activities for your interest in becoming an engineer?	Likert
Q7-pre	In one sentence, describe what an engineer looks like.	Free response
Q8-pre	List hands-on activities that you credit for your interest in becoming an engineer. Examples of hands-on activities include: working on family vehicles, helping out with building things around the house, maintaining farming and hunting equipment, installing computer programs and entertainment systems, school projects or clubs, etc. Identify any hands-on activity that you think influenced your interest in becoming an engineer.	Free response
Q9-pre	In one sentence, describe a valuable service or a valuable product that you hope to create, improve, maintain, or innovate as an engineer after you graduate.	Free response
Q10-pre	In one sentence, describe your greatest strength as an engineering student.	Free response

A. Engineering Self-Efficacy

To probe students' engineering self- efficacy, we focus on 1) questions Q1-pre and Q1-post (see Tables II and III) regarding students' confidence in their ability to succeed as an engineer and 2) questions Q2-pre and Q7-post (see Tables II and III) regarding students' confidence in their ability to learn the skills necessary to be an engineer.

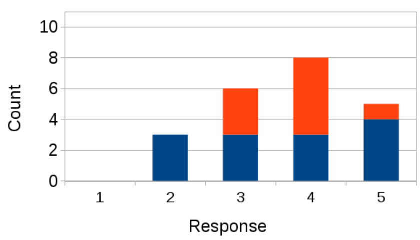
1) Confidence in Ability to Succeed: We present a histogram of student responses to questions Q1-pre and Q1-post in Fig. 1 and additionally present mean responses plus and minus standard deviation in Table IV. We note similar pre-intervention confidences across the three cohorts and between Hispanic and non-Hispanic students indicating similarly diverse cohorts as far as confidence. Comparing the pre- and post-intervention confidences, we see a general trend of increasing confidence across all cohorts and demographics. This can be seen in an increase in the mean response (Table IV) and in a right-ward shift and compression of the histogram toward more positive responses (Fig. 1). Effects across the cohorts were mixed, with non-Hispanic students reporting slightly higher confidence in the Light and Heavy Intervention cohorts and Hispanic students reporting the opposite; these differences are all within the standard deviation (Table IV).

2) Confidence in Ability to Learn Skills: We present a histogram of student responses to questions Q2-pre and Q7-post in Fig. 2 and additionally present mean responses plus and minus standard deviation in Table V. We note similar pre-intervention confidences across the three cohorts and between Hispanic and non-Hispanic students, again indicating similarly diverse cohorts. Comparing the pre- and post-intervention confidences, we see a general trend of increasing confidence across all cohorts and demographics; we again see this in an increase in the mean response score (Table V) and in a right-ward shift and compression of the histogram toward more positive responses (Fig. 2). Effects across the cohorts were similar, with the exception of a slightly lower score for the Light Intervention cohort in the post-survey; differences are again within the standard deviation (Table V).

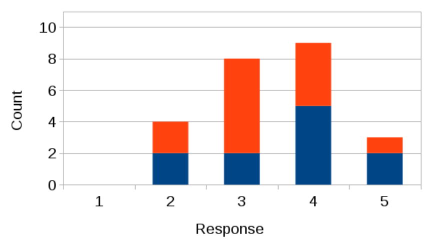
From the results on questions related to engineering self-efficacy, it appears that participation in a first-year engineering course itself may have more influence on students' engineering self-efficacy than the specific level of EML. One interpretation of these data is the general fact that first-year students gain significantly in confidence simply by taking introductory courses, thus emphasizing the value of a cross-curriculum first-year engineering course sequence. However, beyond this, we recognize that there may be a variety of factors that impact whether or not students feel confident, which might range from participating in the EML content, as well as the faculty instructors, mentorship, tutoring, or many other social dynamics during that given semester. Moreover our data only include the general self-efficacy questions, whereas probing specific types of self-efficacy may allow us to identify more subtle but significant differences.

TABLE III
POST-INTERVENTION SURVEY QUESTIONS. QUESTIONS WITH LIKERT-STYLE RESPONSES HAD OPTIONS OF NOT AT ALL, SLIGHTLY, MODERATELY, VERY, AND EXTREMELY.

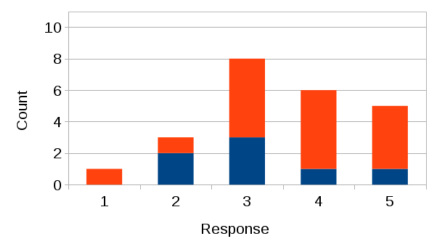
Question #	Question	Question Type
Q1-post	Regardless of your current grades this semester, how confident are you in your ability to succeed as an engineering student through graduation?	Likert
Q2-post	Regardless of your current grades this semester, how confident are you that you will continue to pursue a career in engineering?	Likert
Q3-post	Whether or not you continue in engineering, how confident are you in your ability to succeed as a college student through graduation?	Likert
Q4-post	How confident are you in your ability to create value for a customer?	Likert
Q5-post	How often does your curiosity about a problem lead to new ways of solution thinking? For example, you may have been more curious about the card tower design challenge than the pulley system design challenge, so your curiosity led you to think outside the box?	Likert
Q6-post	How confident are you in your ability to make connections? For example, you may have made connections with your design challenge teammates.	Likert
Q7-post	How confident are you in your ability to learn the skills required to be an engineer?	Likert
Q8-post	How confident are you in your ability to become the engineer that others expect you to be?	Likert
Q9-post	How confident are you in your ability to become the engineer that you want to be?	Likert
Q10-post	In one sentence, describe your main source of confidence. What gives you the self-confidence to attempt success?	Free response



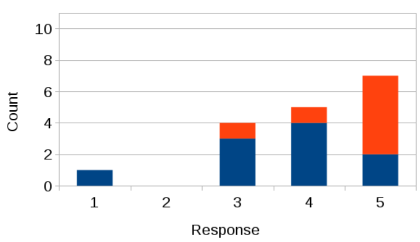
(a) Control, Q1-pre.



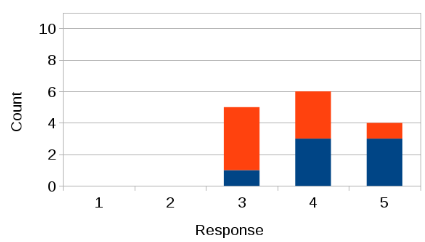
(b) Light intervention, Q1-pre.



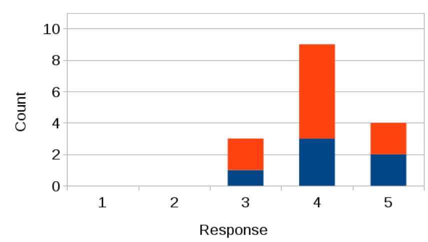
(c) Heavy intervention, Q1-pre.



(d) Control, Q1-post.



(e) Light intervention, Q1-post.



(f) Heavy intervention, Q1-post.

Fig. 1. Number of students per response for the questions Q1-pre and Q1-post regarding confidence in students' ability to succeed as an engineer. Responses were coded as (1) Not at all, (2) Slightly, (3) Moderately, (4) Very, and (5) Extremely confident. Results are presented as a stacked bar chart with red indicating Hispanic students and blue the remainder.

TABLE IV
PRE- AND POST-INTERVENTION RESPONSE SCORES PRESENTED AS AVERAGE $\pm$ STANDARD DEVIATION FOR Q1-PRE AND Q1-POST REGARDING CONFIDENCE IN STUDENTS' ABILITY TO SUCCEED AS AN ENGINEER. SEE FIG. 1 FOR A DESCRIPTION OF THE RESPONSE CODING. THE TOTAL COLUMN REFLECTS THE AVERAGE OVER ALL STUDENTS (HISPANIC AND NON-HISPANIC).

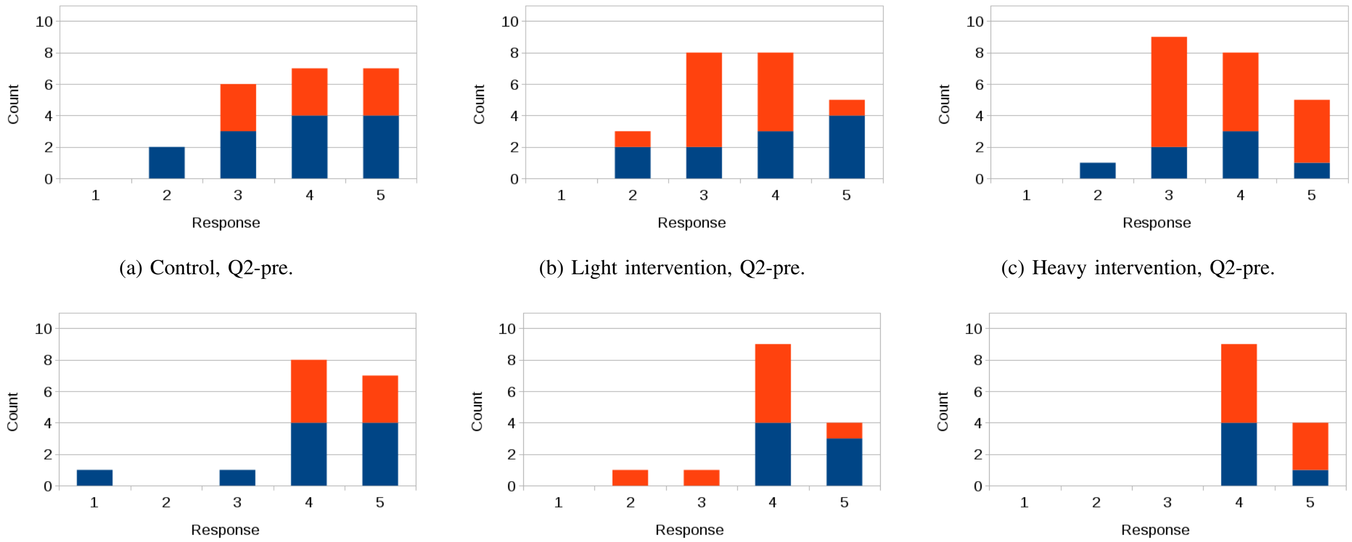
	Total		Hispanic	
	Q1-pre	Q1-post	Q1-pre	Q1-post
Control	3.68 ± 0.99	4.00 ± 1.12	3.78 ± 0.67	4.57 ± 0.79
Light	3.45 ± 0.93	3.93 ± 0.80	3.31 ± 0.85	3.63 ± 0.74
Heavy	3.48 ± 1.12	4.06 ± 0.68	3.63 ± 1.15	4.00 ± 0.67

TABLE V
PRE- AND POST-INTERVENTION RESPONSE SCORES PRESENTED AS AVERAGE $\pm$ STANDARD DEVIATION FOR Q2-PRE AND Q7-POST REGARDING CONFIDENCE IN STUDENTS' ABILITY TO LEARN THE SKILLS NECESSARY TO SUCCEED AS AN ENGINEER. SEE FIG. 2 FOR A DESCRIPTION OF THE RESPONSE CODING. THE TOTAL COLUMN REFLECTS THE AVERAGE OVER ALL STUDENTS (HISPANIC AND NON-HISPANIC).

	Total		Hispanic	
	Q2-pre	Q7-post	Q2-pre	Q7-post
Control	3.86 ± 0.99	4.18 ± 1.01	4.00 ± 0.87	4.43 ± 0.53
Light	3.63 ± 0.97	4.07 ± 0.80	3.46 ± 0.78	3.75 ± 0.89
Heavy	3.74 ± 0.86	4.06 ± 0.68	3.81 ± 0.83	4.10 ± 0.74

B. Entrepreneurial Mindset

We use question Q3-pre (Table II) as an assessment of students' interest in value creation as well as innovation and entrepreneurship activities prior to any knowledge of EML. Although the EML mindset is not about being an entrepreneur, per se, we asked this question in order to query



(a) Control, Q2-pre. (b) Light intervention, Q2-pre. (c) Heavy intervention, Q2-pre.

(d) Control, Q7-post. (e) Light intervention, Q7-post. (f) Heavy intervention, Q7-post.

Fig. 2. Number of students per response for the questions Q2-pre and Q7-post regarding confidence in students' ability to learn the skills necessary to succeed as an engineer. Responses were coded as (1) Not at all, (2) Slightly, (3) Moderately, (4) Very, and (5) Extremely confident. Results are presented as a stacked bar chart with red indicating Hispanic students and blue the remainder.

whether creation of value was on the mind of our first-year students. Histograms of responses for students' level of interest in entrepreneurial endeavors are presented in Fig. 3 and means and standard deviations of responses are shown in Table VI. We were interested in whether student answers were different for different cultural backgrounds because many of our underrepresented students share an interest in hands-on and prototyping activities. Interestingly, the responses to this question were not different across the cohorts nor between Hispanic and non-Hispanic students. This indicated that our cohorts valued innovation similarly and can be interpreted as all starting with a similar entrepreneurial mindset. We next assess post-intervention survey questions probing the "three C's" of EML: creating value, curiosity, and connections. We present and discuss these results together since the trends for these three post-intervention survey questions track each other.

We use question Q4-post as an assessment of student confidence in value creation, Q5-post to assess students' opinion of the importance of curiosity for problem-solving, and Q6-post to assess student confidence in making connections (see Table III for detailed question text). Histograms of these responses are presented in Fig. 3 with the mean and standard deviations reported in Table VI. Based only on these general questions, we observed no significant difference between cohorts or between Hispanic and non-Hispanic students. Again, the values compared were the metrics compiled from averages of the Likert-style scale.

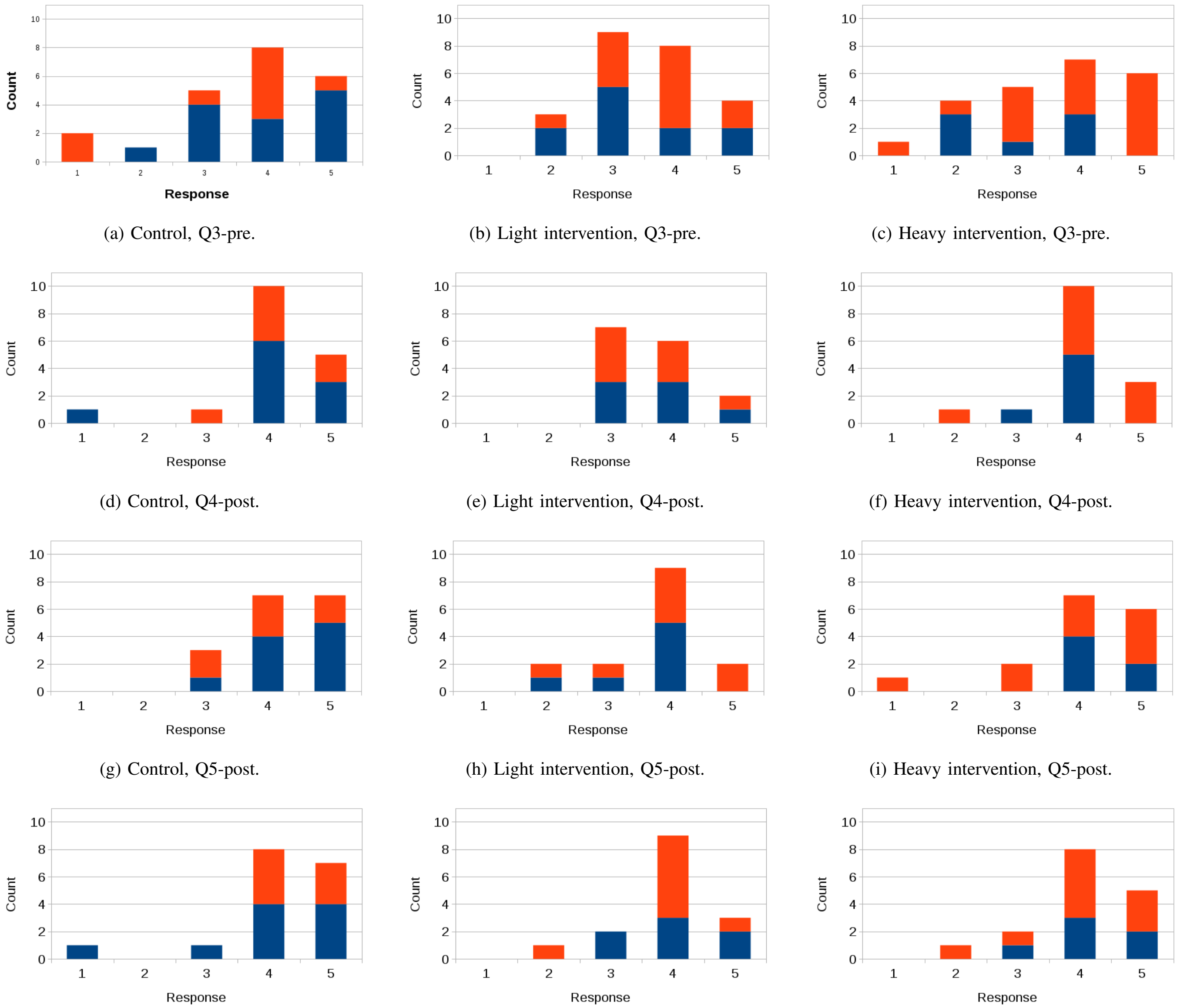
Although there was not an obvious differentiation across the cohorts who did and did not receive instruction based on EML modules, other trends were observed, and we believe other evidence collected anecdotally revealed aspects of how our efforts to include EML did affect students. Firstly, we note a trend in a positive direction, in which responses were more likely to be confident and interested (see Table VI), occurred for all cohorts. This again might be owing to the valuable aspects of participating in a first-semester engineering course, or simply a higher level of familiarization after taking the class. Secondly a marked difference was observed by the course instructor when comparing the Light Intervention and Heavy Intervention cohorts (recall that these two cohorts shared the same course instructor). That is, the quality of reporting was starkly different by students in their discussion of the problem, the proposed solution, and in their relation of that design problem to the "bigger picture." The Heavy Intervention cohort were much stronger in this skill than the Light Intervention. We believe that our efforts to work heavily with students on understanding EML and making their projects relevant to them culturally manifested in the quality of the work produced rather than self-efficacy of the students. We plan to study differences in course performance across the three cohorts in future work to quantify our qualitative observations regarding student work.

C. Open-Ended Questions

In addition to the Likert-scaled questions, we queried students to collect open-ended responses. Many of our questions sought to understand how students perceive engineers and whether their social-identity drives their identification with engineering and as an engineer (see Tables II and III).

1) Qualitative Survey Questions Pre-Intervention:

a) Q7-pre: This question (see Table II for full question text) was designed to assess social identity as an engineer. It was worded to be potentially provocative in the sense that it might elicit statements reflecting stereotypes. However, no respondents in any of the cohorts identified race, ethnicity, or gender in their description of an engineer. Interestingly,



(a) Control, Q3-pre. (b) Light intervention, Q3-pre. (c) Heavy intervention, Q3-pre.

(d) Control, Q4-post. (e) Light intervention, Q4-post. (f) Heavy intervention, Q4-post.

(g) Control, Q5-post. (h) Light intervention, Q5-post. (i) Heavy intervention, Q5-post.

(j) Control, Q6-post. (k) Light intervention, Q6-post. (l) Heavy intervention, Q6-post.

Fig. 3. Number of students per response for the questions Q3-pre (interest in entrepreneurship), Q4-post (confidence in creating value for a customer), Q5-post (how often curiosity leads to new solutions), and Q6-post (confidence in making connections). Responses were coded as (1) Not at all, (2) Slightly, (3) Moderately, (4) Very, and (5) Extremely interested/confident/often. Results are presented as a stacked bar chart with red indicating Hispanic students and blue the remainder.

one student response reflected a mild offense at the question, indicating that they did not feel an engineer would differ in appearance from others.

b) Q8-pre: This question (see Table II for full question text) was designed to assess pre-college activities that may have contributed to engineering self-efficacy. Responses were categorized according to the type of activities students experienced, for example, working on cars, building model rockets, or participating in school-related science fairs. Of particular interest to this study was the role of family in engineering formation (i.e., implication of differences in ethnicity and cultural background); thus responses that included any mention of family were coded as “family-related” activities. Approximately 34% of pre-survey responses were coded as “family-related” activities. More self-identified Hispanic students (approximately 52%) credited family-related activities for their interest in becoming an engineer.

c) Q9-pre: This question (see Table II for full question text) was designed to assess student perception of effectual thinking skills and their importance in engineering. We anticipated that questions about value creation asked pre-intervention would reveal a deficit in students’ realization of the importance of entrepreneurial mindset. With this an open-ended question, we categorized responses according to general answers. For example, students who responded about a desire to work for NASA were coded in the “Space” category. Of

TABLE VI

PRE- AND POST-INTERVENTION RESPONSE SCORES PRESENTED AS AVERAGE $\pm$ STANDARD DEVIATION FOR Q3-PRE, Q4-POST, Q5-POST, AND Q6-POST REGARDING ENTREPRENEURSHIP, CREATING VALUE, CURIOSITY, AND CONNECTIONS. SEE FIG. 3 FOR A DESCRIPTION OF THE RESPONSE CODING. THE TOTAL COLUMN REFLECTS THE AVERAGE OVER ALL STUDENTS (HISPANIC AND NON-HISPANIC).

	Total				Hispanic			
	Q3-pre	Q4-post	Q5-post	Q6-post	Q3-pre	Q4-post	Q5-post	Q6-post
Control	3.68 ± 1.21	4.06 ± 0.97	4.24 ± 0.75	4.18 ± 1.01	3.33 ± 1.41	4.14 ± 0.69	4.00 ± 0.82	4.43 ± 0.53
Light	3.54 ± 0.93	3.67 ± 0.72	3.73 ± 0.88	3.93 ± 0.80	3.69 ± 0.85	3.63 ± 0.74	3.88 ± 0.99	3.88 ± 0.83
Heavy	3.56 ± 1.20	4.00 ± 0.76	4.06 ± 1.06	4.06 ± 0.94	3.81 ± 1.22	4.11 ± 0.93	3.90 ± 1.29	4.00 ± 0.94

note was the approximate 28% of respondents categorized as "Human Health and Well-being," representing service-related work such as improving water systems or creating better prosthetics. In terms of other general categories of responses, all three cohorts had varied answers with no additional prominent categories. We noted no specific differences between Hispanic and non-Hispanic student responses. These responses reflect the fact that all three cohorts recognized the general importance of an engineering product the value created for human benefit. We recognize that this awareness is quite different from students actually seeking added value in the problems presented in class (i.e., the goal of the EML mindset).

2) Qualitative Survey Questions Post-Intervention:

a) Q10-post: This was the only open-ended question asked on the post-survey, and it was designed to assess what students identified as sources of their self-efficacy (see Table III for full question text). Responses were categorized as Personal Trait (e.g., determination, faith), Academic Achievement (e.g., good grades), Family, Interest in Engineering, Future Aspirations (e.g., wanting a good life, ability to make money), Desire to Help Others (e.g., making the world a better place), and one or more of the three C's of EML (curiosity, connections, or creating value mentioned specifically).

Approximately 40% of the Control, Light Intervention, and Heavy Intervention cohorts total ($N = 48$ for post-survey responses) identified a Personal Trait as their main source of confidence on the post-survey, making Personal Trait the leading category of response, followed by Academic Achievement at approximately 27%. Among the 18 students who identified a Personal Trait as their main source of confidence on the post-survey, approximately 33% of them identified "Determination," making it the leading type of Personal Trait, followed by "Belief in Myself" at approximately 17%.

The cohort that received the most exposure to EML was the Heavy Intervention cohort ($N = 17$ post-survey response). Compared to the other two cohorts, the Heavy Intervention cohort identified Academic Achievement as their main source of self-confidence (approximately 41%), followed by Personal Trait (approximately 24%). Personal Trait was the leading source of self-confidence identified in the Control cohort (approximately 50%) and Personal Trait was the leading source of self-confidence identified in the Light Intervention cohort (approximately 47%), followed by Academic Achievement in the Control cohort (approximately 25%) and followed by Interest in Engineering in the Light Intervention cohort (approximately 20%). Only one response out of all students who responded to Q10-post was categorized as fitting the definition of one or more of the "three C's" of EML. That response was from a student in the Heavy Intervention cohort who specifically answered with all three "C's".

Overall, results suggest that when compared to the Control cohort, first-year engineering students who received Heavy Intervention exposure to EML are more likely to recognize Academic Achievement as a source of self-confidence (Control, approximately 25% answered Academic Achievement; Heavy Intervention, approximately 41%). It is notable that post-survey results suggest exposure to EML increases first-year engineering students' recognition of their own pursuit of knowledge being integrated with solutions (Academic Achievement) as a main source of their self-confidence and thus a potential main source of their self-efficacy.

IV. CONCLUSION AND FUTURE WORK

Our study was designed to understand the influencing factor of ethnicity on self-efficacy while students are engaged in EML. To best summarize the collective results, we analyzed data from Likert scale surveys as well as from answers collected when students were asked to reflect on topics such as confidence level and identity as engineers. Quantitative data were presented as mean responses, and we note that summarizing in this way allows us to draw only broad conclusions when comparing our experimental and control groups. Although the EML-specific classes did not have obvious differences, we did find changes before and after course completion. One important aspect, perhaps, is the fact that the courses with EML were only implemented periodically with mindset-designed projects and not throughout the entire course. Additionally, course instructors did not teach with EML focused material. We are nonetheless inspired by EML focused content and by the idea that it, along with the experiential engineering characteristics that Hispanic students bring to our program, are qualities and concepts that work together to impart the T-skills our students need for succeeding at a global level. Future work will include more analysis of open-ended answers, summarizing our observations of the EML-activities and finding ways to best quantify self-efficacy. Additionally we are interested in determining the impact of EML on our Hispanic students when fully exposed to a course designed for EML.

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