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How Student Characteristics Shape Engineering Pathways to Entrepreneurship Education*

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As higher education works to meet the challenges of the changing economy, engineering programs have significantly increased their programs in entrepreneurship as a mechanism for fostering 21st century skills in a diverse workforce. In an effort to balance the rigorous academic technical requirements of an engineering degree, entrepreneurship programs leverage both curricular and co-curricular programming, offering students different paths to entrepreneurship development. However, little is known about the distribution of these opportunities amongst different groups of students. The purpose of this investigation is to examine whether the pathways to entrepreneurship education are influenced by student characteristics. Institution and participation data of 1,018 undergraduate students were collected from an entrepreneurship program anchored in a large, Midwest, public research university, college of engineering, center for entrepreneurship. Logistic regressions were used to examine the differences and similarities between students enrolling an entrepreneurship curricular program and their participation in co-curricular activities. Our data indicates that gender, nationality, and grade point average (GPA) are key factors in determining the type of entrepreneurship participation students choose to pursue in the university environment. We also found evidence of the curricular program acting as a gateway to engagement with entrepreneurship beyond the classroom. These data suggest that entrepreneurship programs should be cognizant of the influencers as well as the student pathways when developing programs to attract a diverse student base.

Keywords: engineering entrepreneurship education; co-curricular activities

1. Introduction

In recent years, engineering education has been experiencing a period of innovation [1–3]. The rising cost of higher education, the changing global economy, an emphasis on career opportunities and advances in understanding student learning, have spawned the creation of new initiatives across institutions to better prepare students to enter the 21st century workforce [4–6]. While it is commonly accepted that engineering graduates must be technically adept, this is no longer seen to be sufficient. The responsibilities of a working engineer have moved beyond technical problem solving and supporting the establishment [7]. Engineers are now expected to play a role in market creation and identifying unmet needs that can be addressed with technical innovations [7]. In the words of the National Science Foundation "the engineering profession must be responsive to national priorities, grand challenges, and dynamic workforce needs; it must be equally open and accessible to all" [8]. Thus, as institutions responsible for developing tomorrow's human capital, universities and colleges have actively been exploring various means of higher level of engineering student development, innovation and inclusion [2, 9]. One of the more common innovations being implemented is engineering specific entrepreneurship programs [10–12].

Historically, higher education entrepreneurship has largely been considered a sub-discipline of business and offered as an elective course in business schools. Business school entrepreneurship courses have traditionally focused on business skills, business planning and case studies [13, 14]. In recent years, engineering schools have begun to promote entrepreneurship education as a mechanism for the development of an innovative engineering workforce [15–18]. Within engineering schools, faculty and staff have worked within the constraints of engineering curricula and leveraged advances in student learning research to offer a wide variety of entrepreneurship opportunities to their students, from single courses to comprehensive programs that offer certificates/minors or majors to extensive co-curricular programming, such as students startup accelerators, trips to entrepreneurial ecosystems, and hacker competitions [18].

The reliance on co-curricular programming for entrepreneurship education poses an interesting question when considering best practices for fostering an innovative engineering profession, particularly with regard to inclusivity. While entrepreneurship education is becoming the commonly

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accepted mechanism for developing an innovative workforce of tomorrow, it is also known that diversity plays a strong role in workforce innovation [19–21]. Thus, it is critical that we examine how current approaches to entrepreneurship education impact diversity and inclusivity. Do varying types of entrepreneurship education opportunities influence students' pathways to entrepreneurship education opportunities differently across multiple sociodemographic groups? We address this question through examining how student characteristics relate to student pathways to entrepreneurship education opportunities as a function of grade point average (GPA), underrepresented minority and international status, and gender.

2. Literature review

2.1 Student participation in engineering entrepreneurship programs

This study investigates the difference between students enrolled in an entrepreneurship curricular program and those who participated in entrepreneurship co-curricular experiences with respect to sociodemographic and academic differences. Unfortunately, few studies describe entrepreneurship education programs (e.g., participation, learning outcome assessments) or entrepreneurial constructs (e.g., entrepreneurial intent) with respect to student data from a single, existing engineering entrepreneurship program. Most empirical engineering entrepreneurship education studies assess entrepreneurial intent [22–24] across several programs to examine the underlying relationship between intention, participation, and skills (e.g., leadership, creative thinking) [24–30] or investigate the impact of entrepreneurship education on student outcomes (e.g., retention) [12]. However, with notable exceptions [24, 27, 31], these studies do not consider students' sociodemographic characteristics to evaluate or assess programs.

The few entrepreneurship studies that have looked at sociodemographics of students participating in entrepreneurship curricula have resulted in conflicting results. The Duval-Couetil et al. (2012) multi-institutional study of engineering capstone courses found that while engineering major played a significant role in student participation in entrepreneurship courses, gender, race, citizenship, and entrepreneurial parents were not significant factors. In contrast, Jin et al. (2014) found that among engineering students, males have higher entrepreneurial intent and greater rates of entrepreneurial activities (e.g., starting a club or business) than females. Ohland et al. (2004) reported that while females were substantially underrepresented in a specific engineering entrepreneurship program, active recruiting increased the number of female participants. On the contrary, Bilén et al. (2005) reported that a minor in entrepreneurship enrolled a significantly higher proportion of females than the existing proportion of females in the engineering school as a whole. They also found that students in the minor had higher math and verbal SAT scores than the general student population in the school.

2.2 Co-curricular involvement in engineering and entrepreneurship education

The role of co-curricular experiences in engineering education, and in higher education in general, has been a growing topic of research for several years. Co-curricular experiences have been shown to increase student engagement [32], enhance self-directed autonomy [33], nurture leadership [34], foster pluralism orientation [35] and intergroup learning [36], and enrich ethical decision making [37]. These studies consistently demonstrate the positive impact of co-curricular experiences. This suggests that co-curricular entrepreneurship education also has the potential to add significant value to students. Thus, the deliberate use of multiple forms of co-curricular activities in entrepreneurship education demands a critical assessment of engineering student entrepreneurship learning, how students choose to engage in entrepreneurship learning, what they learn from the different experiences, and how the experiences influence their view of entrepreneurship.

In the few articles that describe entrepreneurship programs and provide corresponding student data, we identified a diverse set of co-curricular experiences that have been studied with respect to impact on student participation and learning outcomes. While it is often assumed that participation in entrepreneurial experiences beyond the classroom are critical for developing the entrepreneurial mindset and entrepreneurial knowledge and skills [27, 31, 38], these experiences are often clustered together with little analysis of structure, levels of institutional support, or levels of student participation. For instance, Duval-Couetil et al. (2012) used a wide range of "entrepreneurship-related activities" to compare the involvement of students who did and did not participate in entrepreneurship courses. These activities included the experiences of conducting a market research, giving an "elevator pitch," writing a business plan, participating in a non-credit entrepreneurship workshop, and participating in student entrepreneurial organizations. Duval-Couetil et al. (2012) found that students who did participate in entrepreneurship courses were significantly more involved in all these activities than those who did not take at least a course. The individual impact of each activity has yet to be studied. Jin et al. (2014) distinguished between entrepreneurial activities (e.g., starting a club, designing a new product or service, developing a business plan) and extra-curricular activities (e.g., participation entrepreneurship clubs or young professional associations). Carpenter and Fierfeil (2007) mentioned "embedding entrepreneurship beyond the classroom" as a strategy for "expanding the learning experience without additional credit hours" (pp. 6, Strategy 5). Among these experiences, the authors suggested supporting a student organization, participation in conferences, and networking activities with students at other schools.

In summary, this literature review demonstrates that empirical studies of entrepreneurship programs often overlook sociodemographic characteristics and simplify the conceptualization of co-curricular experiences, suggesting a vague alignment with the curriculum. In this study, we begin to explore the relationship between student characteristics and their engagement in entrepreneurship education through curricular and co-curricular experiences in the context of college experience models. In the next section, we first discuss the most well known models of college experience in higher education and then introduce an engineering entrepreneurship impact model that will serve as the conceptual framework for this study.

3. Theoretical overview

3.1 College experience models

The role of student involvement in higher education is well researched with respect to Astin's 1985 Theory of Student Involvement [39] and his input-environment-output (I-O-E) model [40, 41]. Astin's I-O-E model integrates a wide range of students' motivations and behaviors that go beyond the student interest in a specific subject matter to better understand how college affects students. Fundamentally, "the greater the student's involvement in college, the greater will be the amount of student learning and personal development" ([44] pp. 528–529).

The I-O-E model provides a framework for studying the impact of institutional environment on student development over time [40]. This model accounts for the personal qualities students bring to the institution, thus providing less biased interpretations when comparing effects of different institutional environments on graduating students. Input variables to the model, otherwise known as the control variables, are student characteristics prior to enrollment, including demographics, family background, and academic history. The environment is characterized by the student experiences while in the program. Output variables, the dependent variables, are the skills, knowledge, attitude, behaviors and affects held by students after the college experience.

Since the introduction of Astin's model, several researchers have worked to further develop I-O-E models and apply them to engineering education in various ways [6, 42, 43]. In 2005, Terenzini and Reason developed their first year college impact model. In their model, Terenzini and Reason presented a comprehensive, integrated view of the first year college experience to study how the environment can influence student learning and persistence. The added level of detail and incorporation of institutional policy, programming, structures, and culture, have offered researchers and administrators an ability to provide actionable feedback to improve institutional effectiveness. More importantly, Terenzini and Reason (2005) found that "the magnitude of change on any particular variable or set of variables during the undergraduate years may not be as important as the pronounced breadth of interconnected changes" (p. 578), only reinforcing the importance of including the interconnectivity of the varied environmental influences. While the Terenzini and Reason college impact model was developed for the first year experience, the model can easily be adapted to other aspects of the undergraduate experience.

Recently, Lattuca et al. (2014) used the Terenzini and Reason model to inform their Prototype to Production: Conditions and Processes for Educating the Engineer of 2020 study. The purpose of this study was to examine to what extent undergraduate engineering programs were effectively preparing "engineers of 2020" as defined by the National Academy of Engineering [44] and to what extent engineering faculty, administrators and staff promote the Engineer 2020 attributes in their courses, curriculum and co-curricular activities. Interview and survey data were collected from engineering students, alumni, faculty and administrators from across the United States. The interview questions were guided by the Terenzini and Reason model and a summary of the responses provided comprehensive recommendations for engineering education improvement at the course, program, and institutional level. Models of student college experiences have been applied to the study of the role of co-curricular programming in student ethical development [43], the structure of interdisciplinary programs [45], and pluralism [35], examining the level of institutional support, faculty commitment, student engagement, and curricular alignment.

3.2 Engineering entrepreneurship I-O-E impact model

For this study, we have chosen to adapt a college experience model to engineering entrepreneurship education and use it as our conceptual framework. This offers us a comprehensive theoretical construct for studying student experiences and resultant outcomes. With the rapid rise in engineering entrepreneurship education programs and increasing dependence of co-curricular activities for student formation, this model offers an integrated approach to studying the impact of environmental factors and examination of the influence of interconnected programs, culture and structure; thus, moving the discipline beyond single variable studies.

In this case, we have chosen to apply the I-E-O model to a more controlled programmatic environment, specific to engineering entrepreneurship education, where both curricular and co-curricular programming are directly aligned with entrepreneurship learning objects, knowledge and skills (Fig. 1). This controlled approach enables us to begin to deconstruct the influence of specific input characteristics and environmental factors on student choices in entrepreneurial development through higher education. Whereas the Terenzini and Reason model looks at the entire college experience, we confine the model to the "University Entrepreneurship Ecosystem." Like the Terenzini and Reason Model, we define three primary influencers on engineering entrepreneurship student outcomes: (1) organizational climate, (2) peer environment, and (3) the individual student experience. In our case, we have specifically defined these influencers in the context of entrepreneurship. For instance, the organizational climate for engineering entrepreneurship can be defined as the overall organization entrepreneurship climate that is really dependent on: (1) the internal structures and policies in support of entrepreneurship (e.g., technology transfer, dean's and provost offices, university acknowledgement of entrepreneurship in the tenure process); (2) entrepreneurship academic and co-curricular programs, policies and practices (e.g., courses, certificates, minors, college-supported competitions); and (3) faculty entrepreneurship culture (e.g., faculty patent and start-up activity), each of which is distinctly different from the overall college experience organizational context. The peer environment is contextualized as the student entrepreneurship culture, while the engineering entrepreneurship individual student experience is the interaction between the student's engineering discipline, his or her involvement in entrepreneurship co-curricular experiences and his or her entrepreneurship classroom experience. Where we depart from the Terenzini and Reason model is with the introduction of a fourth influencer: University links to the external entrepreneurial community where students have access to the local economic development community, mentorship and a density of entrepreneurial opportunities. The university engagement with the local entrepreneurial community has been identified as a critical component of a vibrant entrepreneurial experience for both students and local business leaders [46, 47].

This study focuses on input variables and the entrepreneurship education environment, specifically curricular and co-curricular opportunities. This distinction specifically provides the opportunity for the study of the influence of student characteristic on student choice of entrepreneurship education paths. In this paper, we specifically address the influence of sociodemographic characteristics on students' paths to entrepreneurship education, focusing on co-curricular and curricular activities (Fig. 1: shaded box).

3.3 The co-curricular experience

While the value of undergraduate co-curricular involvement is well researched [33, 34, 37], the influence of different experiences in a complex higher education environment has yet to be understood. To date, the majority of co-curricular research has largely been two dimensional, examining the impact of individual characteristics and levels of participation on broad outcomes, such as ethical decision making [37], intergroup learning [36], and student engagement [32]. What this body of literature neglects to address is the diversity of experiences available to college students today and exploring how students from different sociodemographics choose to engage or not in these diverse experiences. Little is known about how students choose to engage in programs, their decision processes and influencers and self-agency. For instance, while Astin (1993) broadly found that college men have a tendency to be overrepresented in in leadership positions, Chachra et al. (2009) found that female engineering students more likely to take on administrative leadership positions while their male counter-parts opted for more hands on design activities [48]. These studies did not look at how students chose to be involved in specific activities with respect to other options nor do they ask what factors influenced students to choose specific curricular paths. These findings suggest that it is important to study what makes one student participate in specific co-curricular activities versus not. In this study, we are holding the co-curricular activity constant and looking at the path students choose to take.

Co-curricular participation is particularly important in entrepreneurship education. While best practices for entrepreneurship education is still under debate, entrepreneurship educators and researchers agree that entrepreneurship education

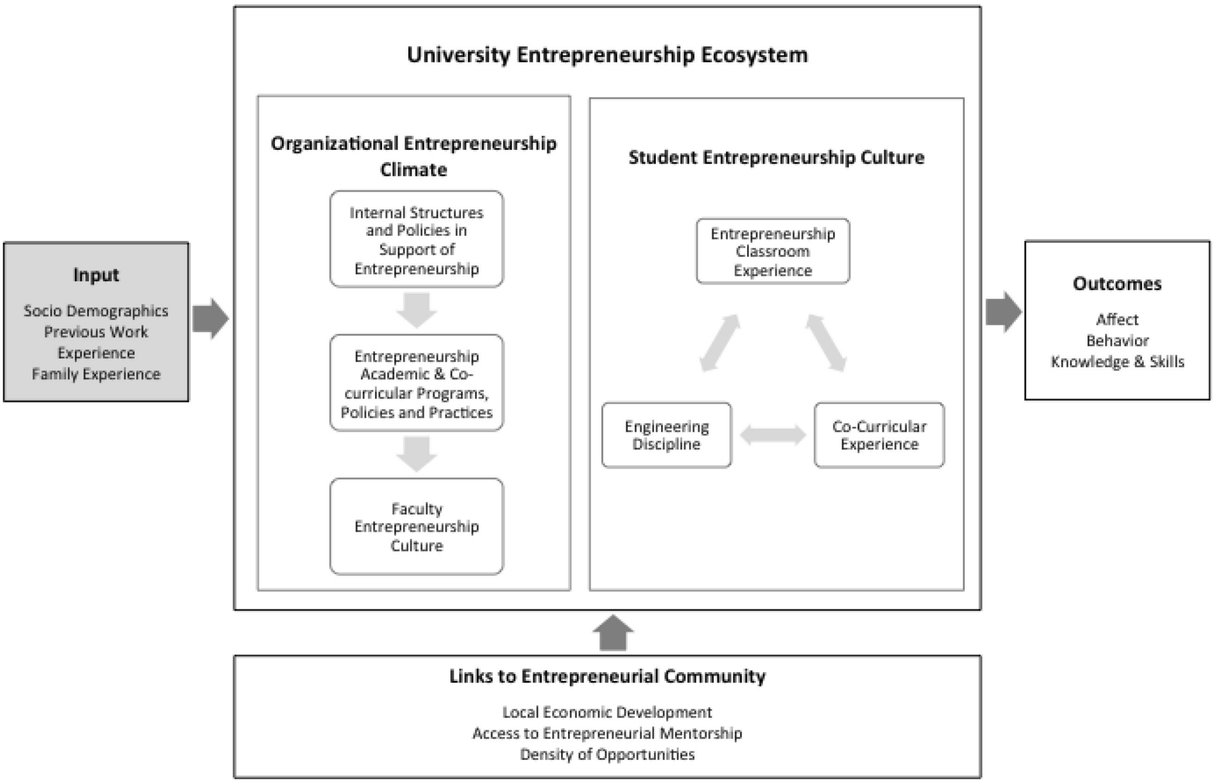

Fig. 1. I-O-E Model for Studying the Impact of Engineering Entrepreneurship Education Environment on Engineering Student Development.

is distinctive in that it requires aspects of project based learning or action based learning with feedback from practitioners [49]. Many institutions offer these learning experiences through co-curricular experiences. By using the proposed engineering entrepreneurship impact model, it is possible to have a better understanding of the paths that students choose when pursuing entrepreneurship education, the outcomes as a result of these paths and the value of the informal versus formal learning that occurs. In this study, we rigorously examine student participation in entrepreneurship curricular and co-curricular experiences. Controlling for the diversity of opportunities available to entrepreneurship students, we focused on a single institution entrepreneurship program that offer the option to participate in a curricular program, as well as co-curricular activities with different levels of institutional support and student engagement. This focus was selected to establish the basic relationships between student characteristics and student selected paths to entrepreneurship education, curricular, co-curricular or both.

Traditionally, the term co-curricular has been used to capture a wide range of learning experiences available to students. This is in contrast to the term extra-curricular which often refers to student experiences outside of the curriculum, but not specific to learning. In some instances, co-curricular experiences are defined by a separation from academic courses, administered by outside organizations or students, or offered outside of the academic calendar for varying durations, offering varied interpretations of the level of student academic engagement, institutional support and academic challenge. This broad definition introduces a challenge when trying to capture the impact of specific programmatic aspects of a co-curricular experience. Thus, for the purposes of this paper, we define entrepreneurial co-curricular experiences as a student, self-selected, non-credit bearing entrepreneurship experience administered by the university and that can be characterized by at least by two different variables, impact on student transformation and level of student involvement. The impact on student transformation refers to the level of student change of knowledge, skills, and attitudes attributed to their participation in co-curricular activities. Level of student involvement, as defined by Astin (1999), represents "the amount of physical and psychological energy that the student devotes to the academic experience" (p. 518). In the context of the entrepreneurial experience student involvement refers to student commitment (e.g., hours of participation, persistence) towards the educationally purposeful activity, such as designing a product or service, participating in competitions, launching a student start-up, organizing an entrepreneurial event, or managing a team.

In summary, based on this theoretical overview, we address the following research question: What is the influence of sociodemographic characteristics (i.e., gender, race and ethnicity, and citizenship), major choice, and academic performance on students' paths to entrepreneurship education, focusing on co-curricular and curricular activities?

4. Methods

4.1 Participants

Student participation data were collected from an entrepreneurship program anchored in a large, Midwest, public research university college of engineering center for entrepreneurship (CFE). Both curricular and co-curricular experiences were supported by CFE at different levels (e.g., staff, training, funding, mentorship). Curricular experiences included individual entrepreneurship courses and a formal 9-credit certificate program, designated the Program in Entrepreneurship (PIE). The formal PIE required students to enroll in a collection of entrepreneurship of courses, including a 1-credit seminar, 3-credit core entrepreneurship course, 2-credit elective and 3-credit capstone practicum course. The program was available to all students on the university campus. Interested students could declare PIE any time after their freshman year.

The co-curricular experiences were extensive with the intent to be able to offer all students an opportunity to engage in entrepreneurship. The suite of co-curricular offerings spanned a range of opportunities, from student led to CFE administered. The primary CFE administered activities included a start-up monetary fund to support student entrepreneurial initiatives (Jump Start Grants), startup treks to Silicon Valley and other entrepreneurial urban centers (Startup Treks), an annual pitch competition (Pitch Competitions), and a student incubator (Student Incubator). The student incubator was an off-campus space for student startup companies to co-locate, work on their startup companies, and interact with the local start-up community. CFE was also involved in other activities that required less monetary funding but more consistent institutional support throughout the academic year. For instance, CFE coordinated numerous mentors (Mentoring), who interacted frequently with students, supported a diverse array of student entrepreneurial organizations (Student Org), and co-sponsored an annual student start-up career fair (Startup Career Fair).

For the purposes of this study, it was necessary to have a better understanding of how each activity contributes to student entrepreneurship development. A panel of CFE faculty and administrators were asked to rank the individual activities with respect to different aspects of student involvement. Based on the responses, we found that faculty and staff observe the impact co-curricular experiences differently with respect to student transformation and student engagement. For this study, we only used co-curricular data from students participating in the Startup Treks and the student incubator because these activities were the two co-curricular experiences that were reported to be the two most transformational experiences administered by CFE. This administration also ensured reliable data collection. Since the first implementation of the Start-Up Trek (2007) and the Student Incubator (2009), the CFE staff kept track of student participation. Similarly, every semester since 2007, CFE documented which students declared PIE. In addition to the lists of students who participated in both the curricular and selected co-curricular activities, student demographic and academic information was requested from the university's registrar office. Data were limited to undergraduate students, as the program was targeted, yet not limited to undergraduates. Overall, our data consists of institutional records of 1,018 undergraduate students who participated in these curricular and co-curricular activities over seven years (2007–2013).

4.2 Dependent variable

Students in our data participated in curricular (PIE) or co-curricular (Start-up Trek or the Student Incubator) activities, or in both types. We sought to understand what factors influenced their decision to engage in one of two co-curricular activities (Start-up Trek or Student Incubator) that demand significant amount of time, preparation, cognitive effort, high delivery of communicational skills, and receive no compensation in terms of academic credits. Therefore, the dependent variable is *participation in co-curricular activities*. This is a dichotomous variable, in which students who participated in co-curricular activities are represented by 1 and students who participated in curricular activities are represented as 0. Figure 2 depicts a Venn diagram of student participation in curricular and co-curricular activities. Students represented in the bottom two circles are those who participated in co-curricular activities. In the figure is also easy to appreciate that there were a low number of students (38 + 7 + 17 = 62) who participated in both, curricular and co-curricular activities. As it will be discussed later in this section, we conducted several analyses with this particular group.

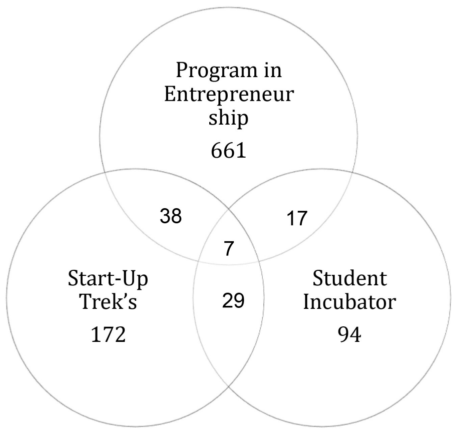

Fig. 2. Student Participation Divided by Entrepreneurial Activities.

4.3 Independent variables

The independent variables studied were selected based on our literature review and those available from the institution registrar: gender, nationality, race and ethnicity, major and GPA. *Gender* was of particular interest because of its reported influence in participation in entrepreneurial activities in the literature [10, 27, 50]. Gender was a dichotomous variable, in which males received the value 0, and females the value 1. *Nationality* was also a binary variable where 1 represents international students and 0 U.S. citizens and permanent residents (USPR). The institutional binary variable, underrepresented minority (URM), represented race and ethnicity. The URM variable was limited to USPR only. We were also able to capture each students' *major*. Although CFE was hosted at the College of Engineering, students from across the University participated in CFE programs. Thus, engineering majors were represented by 1 and non-engineering majors 0. Finally, we included GPA information. *Pre-college GPA* was the GPA students reported to the university prior to enrollment and *CumGPA* was the student's cumulative GPA at the time of data collection. We also obtained information regarding family income and parents' educational level. Unfortunately, due to the fact that these two variables are self-reported, numerous values were missing. Nevertheless, we conducted a Chi squared test to look for differences in the co-curricular participation among different levels of family income and parents' education and found no statistically significant differences. For these reasons, results from these two variables are not discussed below.

4.4 Data analysis

Logistic regression analyses were conducted to test the associations between participation in co-curricular activities and gender, nationality, major, and pre-college GPA. For our primary model, we used a Wald likelihood ratio test to assess the simultaneous effects of the independent variables in the model [51] and computed odds ratios to interpret the results. We also computed three additional logistic regressions to assess influences of other subgroups on participation: (1) a binary variable indicating URM was studied under the USPR population; (2) pre-college GPA was replaced with the last college cumulative GPA; (3) finally, we excluded the group of students who participated in both curricular and co-curricular activities. With this particular group, we compared what came first, their participation in the curricular or co-curricular activities. This comparison is discussed at the end of the Results Section.

4.5 Limitations

This investigation attempts to better understand how students that self-select into entrepreneurial educational opportunities and how, if at all, sociodemographics influence student decisions. While the study benefits from institutional data that can be paired with participation data from a single institution, this limits the sample set to a particular institutional context. Therefore, the generalization of the results should be read with caution. At the same time, while the entrepreneurship ecosystem supports numerous co-curricular activities across campus, documentation of involvement is more challenging for student-run programming, limiting the study to CFE administered programming. However, the focus of this study is on co-curricular activities that require high involvement and commitment from both students and the institution. A final limitation of this research is that student curricular participation was defined as students that declared an intent and began to work towards academic completion of the PIE, not those that completed the entire 9 credit program.

5. Results

Table 1 summarizes the descriptive statistics of our sample. Of this sample, 723 students enrolled in the PIE (71%), 357 participated in at least one of the two co-curricular activities organized by CFE (36%), and 62 participated in both curricular and co-curricular activities (6%).

The Wald likelihood ratio test indicates that the logistic regression model is significant, meaning coefficients are not simultaneously equal to zero (Table 2, LR Chi-square = 85.46, $p < 0.01$). In other words, the aggregated effect of the independent variables does explain whether a student will participate in a co-curricular activity. All of the independent variables are statistically significant.

Table 1. Descriptive Statistics of Students and Students' Participation (N = 1,018)

	N	%
Student Participation in entrepreneurial activities:		
Curriculum		
Program in Entrepreneurship (PIE)	723	71
Co-Curriculum		
Start-Up Trek's	246	24
Student Incubator	147	14
Gender:		
Male	724	71
Female	294	29
Citizenship:		
International	100	10
U.S. permanent resident (USPR)	918	90
Race / ethnicity (USPR only):		
Underrepresented minority (URM)	89	10
Non-URM	829	100
Academic program—first semester in the institution:		
Engineering	390	38
Literature, Science, and Arts	580	57
Other (e.g., Business, Education, Kinesiology)	48	5
Academic performance:	Mean	SD
Initial GPA—first semester at the institution	3.25	0.50
Cumulative GPA—last semester registered	3.34	1.16

Holding all variables, except gender, constant or at their means, female students are 40% less likely to participate in co-curricular activities than males. Nationality appears to be a borderline significant variable. Under equal conditions, international students were 44% less likely to participate in co-curricular activities than USPR students. Major enrollment has the strongest influence on co-curricular participation. Engineering students were 145% more likely to participate in co-curricular activities than their peers, holding other variables constant or at their means. Student pre-college GPA also had a positive effect on the likelihood of participation in co-curricular activities. Students with greater pre-college GPA were more likely to participate in co-curricular activities than students with lower GPA. For instance, a USPR engineering female student with a pre-college GPA equal to 4 (from a range from 1 to 4) has 54% chances of participation in co-curricular activities, versus a 35% of a USPR engineering female student with a pre-college GPA of 3.

Table 2. Logistic Regression on Students' Characteristics Associated with Participation in Co-curricular Activities in Entrepreneurship (N = 1018)

	Co-curricular activities			
	B		**SE**	**Odds Ratio**
Constant	–3.36	***	0.16	
Female	–0.51	***	0.25	0.60
International Student	–0.58	*	0.14	0.56
Engineering major	0.90	***	0.15	2.45
Pre-college GPA	0.78	***	0.52	2.19
Log likelihood		–616.80242		
Df		4		
LR Chi-square		85.46***		

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

When international students are excluded from the sample and the URM variable is added into the model, all other independent variables remain statistically significant. According to this model, belonging to an URM does not influence participation in co-curricular activities. When we replaced pre-college GPA with the last cumulative GPA captured for each student in the primary model, the results remained basically the same, including the positive effect of GPA in co-curricular participation. Finally, the results from of all the models do not significantly change when we exclude the group of 62 students who participated in both curricular and co-curricular activities.

A deeper look at the group of the 62 students suggests an interesting pattern. Out of the total, 49 students (79%) declared PIE at least an academic year before participating in the co-curricular activities, and 11 students (18%) started participation in both types of activities over the same academic year. More strikingly, only 2 students (3%) participated in the co-curricular activities at least an academic year before declaring PIE, the curricular path. Thus, in most cases, students who participated in both types of activities started enrolled first in the curricular path.

6. Discussion

In this study, we explore the access to entrepreneurship education opportunities (curricular and co-curricular) on engineering students with respect to gender, nationality, major, and pre-college academic performance. Results from this study have the potential to impact engineering education on several different levels. First, it appears that students follow different paths to entrepreneurship education. Given the complexity of the execution of entrepreneurship education in higher education, its dependence on formal and information learning and its potential, impact on student learning with respect to attitude, behavior and cognition, it is critical we understand the how and why students from different sociodemographic groups select their path to entrepreneurship education. Additionally, we propose that entrepreneurship education appears to be a strong model for examining the complexity of co-curricular involvement on student learning. Thus, having the potential to impact how institutions create a complex array of programming to support student growth and development for all students.

Initially, one of the most striking results was the low student overlap between participation in the curricular and selected co-curricular activities. Most of the students who engaged in the Startup Treks to Silicon Valley and the student startup accelerator did not formally enroll in the entrepreneurship certificate, the curricular path. Thus, these two distinguishable paths triggered our interest in deconstructing the students' participation in this particular entrepreneurial environment.

Interestingly, we found that a larger percent of female participation in entrepreneurship curricular programs than co-curricular activities. Our finding and several sociological findings suggest that a deeper evaluation of entrepreneurship education in relation to gender is worthy of further investigation. Sociological research suggests that males show a higher entrepreneurial intent than females and entrepreneurial education has less of an effect on entrepreneurial intent in males than females [52]. At the same time, previous studies have indicated that females may limit themselves because of a sensed lack of skills [52]. This suggests that formal entrepreneurship education is a more likely path for females than males. Our findings suggest that females may view enrollment into an entrepreneurship course less of a barrier to entry than self-selecting into a competitive entrepreneurial co-curricular experience. In addition, research indicates that females tend seek out communal goals more than males [53]. This may explain why they may be discouraged from participating in some of the more common competitive entrepreneurial opportunities.

Unlike other entrepreneurship quantitative studies, this study is able to leverage a large student sample in a single institutional program with access to institutional data. To date, most entrepreneurship research has generally been focused upon large quantitative survey studies that aggregate educational content, the impact of entrepreneurship education on entrepreneurial intent or firm-creation, or common characteristics shared by successful entrepreneurs across a diverse set of institutions, curricula and pedagogy. These studies offer limited insight into the influence of gender and other individual characteristics on different pathways of entrepreneurship education

We also found that there is no difference in underrepresented minority participation in co-curricular and curricular programs. While we recognize there is value to increasing the overall percentage of participation from these groups for program implementation, in the context of this analysis, consistent participation suggests that these students are not influenced to participate in one path or the other.

Finally, our results indicate that students who only pursued co-curricular experiences for entrepreneurship had higher pre-college GPA than those who enrolled in the curricular program. This result is partially consistent with Bilén et al.'s (2005) finding that students attracted to entrepreneurship programs had higher SAT scores than the general population. However, we do not have a clear answer to the difference we found between the two paths. An alternative explanation is that students with higher academic performance seek more "rigorous" or "challenging" curricular programs that advance their technical knowledge, pursuing their entrepreneurial interest only through co-curricular activities. This alternative deserves further exploration.

The college impact construct presented in this paper also has the potential to have a broader impact on co-curricular involvement and student engagement literature. While the overall impact of student involvement is well established, how students choose to engage in specific opportunities over others is still to be determined. In addition, the level and value of student engagement differs for students from different cohorts (i.e., gender) and disciplines, resulting in some conflicting results. Research has shown that institution wide/program wide evaluation may overlook the needs of specific subgroups of students [54]. Thus, examining the impact of co-curricular activities in engineering entrepreneurship education, offers a more controlled study of co-curricular impact on students. The role of co-curricular experiences is a well-established piece of engineering education. In the case of engineering entrepreneurship, these co-curricular experiences are educationally purposeful and aligned with entrepreneurship, controlling for differences in the impact of educationally purposeful experiences versus non-educationally purposeful [32]. Controlling for these factors, the college experience models can be used to more specifically examine the role of pre-college characteristics on student engagement and the path to entrepreneurship education and the influence of various co-curricular activities on student outcomes.

7. Conclusion

Entrepreneurship education is quickly becoming considered a best practice for developing the innovative workforce of tomorrow in engineering institutions. Over the last several years, engineering entrepreneurship programs have evolved to be comprehensive educational experiences that heavily rely on curricular and co-curricular experiences. As engineering institutions continue to evolve to meet the rapidly changing demands of tomorrow's workforce with this comprehensive approach, we need a better understanding of the interactions between co-curricular and curricular experiences, their impact on learning and how students choose to navigate the numerous opportunities available to them today. Our sample consisted of students who engaged in some form of entrepreneurial education experience in the College of Engineering. Our analysis sought to explain curricular and co-curricular paths of participation based on students' individual characteristics and backgrounds. The fact that almost all the independent variables used in this study, to some extent, explained the variation in participation, have important consequences for institutions that support rich co-curricular environments. In particular, regarding gender and race. Our findings impose the question whether the learning opportunities in engineering schools are distributed equally among diverse group of students in the context of entrepreneurship education. The question of equity of participation is relevant since the rising centrality of entrepreneurship in engineering education and in mainstream culture. This is even more important as schools and universities truly believe that entrepreneurial knowledge, attitudes and skills are critical for contemporary workforce.

References

1. M. C. Clark, J. Froyd, P. Merton and J. Richardson, The evolution of curricular change models within the foundation coalition, *Journal of Engineering Education*, **93**(1), 2004, pp. 37–48.
2. S. D. Sheppard, K. Macatangay, A. Colby and W. M. Sullivan, *Educating engineers: designing for the future of the field*, San Francisco, CA: Jossey-Bass, 2009.
3. R. Graham, *Achieving excellence in engineering education: the ingredients of successful change*, London: The Royal Academy of Engineering, 2012.
4. S. Olson, *Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning: Summary of a Forum*, Washington, D.C.: National Academy Press, 2013.
5. T. Byers, T. Seelig, S. Sheppard and P. Weilerstein, Entrepreneurship: Its Role in Engineering Education, *The Bridge*, 2005, pp. 35–40.
6. L. R. Lattuca, P. T. Terenzini and D. B. Knight, *2020 Vision: Progress in Preparing the Engineer of the Future*, Ann Arbor, 2014.
7. T. J. Kriewall and K. Mekemson, Instilling the Entrepreneurial Mindset into Engineering Undergraduates, *Journal of Engineering Entrepreneurship*, **1**(1), 2010, pp. 5–19.
8. National Science Foundation: Research Initiation in Engineering Formation, 2015. [Online]. Available: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503603.
9. L. R. Lattuca, P. T. Terenzini and D. B. Knight, *E2020 Study Methods*, Ann Arbor, 2014.
10. S. G. Bilén, E. C. Kisenwether, S. E. Rzasa and J. C. Wise, Developing and assessing students' entrepreneurial skills and mind-set, *Journal of Engineering Education*, **94**(2), 2005, pp. 233–243.
11. J. Ochs, T. Watkins and B. Boothe, Creating a truly multidisciplinary entrepreneurial educational environment, *Journal of Engineering Education*, **90**(4), 2001, pp. 577–583.
12. M. W. Ohland, S. A. Frillman, T. K. Miller and N. Carolina, NC State's Engineering Entrepreneurs Program in the Context of US Entrepreneurship Programs, in *The NCIIA 8th Annual Meeting*, 2004, pp. 155–164.
13. G. E. Hills, Variations in University entrepreneurship education: An empirical study of an evolving field, *Journal of Business Venturing*, **3**, 1988, pp. 109–122.
14. W. B. Gartner and K. H. Vesper, Experiments in entrepreneurship education: Successes and failures, *Journal of Business Venturing*, **9**(3), 1994, pp. 179–187.
15. E. F. Crawley, J. Malmqvist, S. Östlund and D. R. Brodeur, *Rethinking Engineering Education: The CDIO Approach*, New York, New York, USA: Springer, 2007.
16. J. J. Duderstadt, *Engineering for a changing world: a roadmap to the future of engineering practice, research, and education*. Ann Arbor, Mich.: The Millennium Project, University of Michigan, 2008.
17. C. J. Creed, E. M. Suuberg and G. P. Crawford, Engineering Entrepreneurship: An Example of A Paradigm Shift in Engineering Education, *Journal of Engineering Education*, **91**(2), 2002, pp. 185–195.
18. T. Standish-Kuon and M. P. Rice, Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities, *Journal of Engineering Education*, **91**(1), 2002, pp. 33–39.
19. N. Bassett-Jones, The Paradox of Diversity Management, Creativity and Innovation, *Diversity, Management, Creativity and Innovation*, **14**(2), 2005, pp. 169–175.
20. K. Talke, S. Salomo and K. Rost, How top management team diversity affects innovativeness and performance via the strategic choice to focus on innovation fields, *Research Policy*, **39**(7), 2010, pp. 907–918.
21. C. R. Østergaard, B. Timmermans and K. Kristinsson, Does a different view create something new? The effect of employee diversity on innovation, *Research Policy*, **40**(3), 2011, pp. 500–509.
22. C. Luthje and N. Franke, The 'making' of an entrepreneur: testing a model of entrepreneurial intent among engineering students at MIT, *R & D Management*, **33**(2), 2003, pp. 135–147.
23. V. Souitaris, S. Zerbinati and A. Al-Laham, Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources, *Journal of Business Venturing*, **22**(4), 2007, pp. 566–591.
24. Q. Jin, S. K. Gilmartin, H. L. Chen, S. K. Johnson, M. B. Weiner, R. M. Lerner and S. Sheppard, Entrepreneurial career choice and characteristics of engineering and business students, *International Journal of Engineering Education*, **32**(2), 2016, pp. 598–613.
25. S. Bilen, E. Kisenwether, S. E. Rzasa and J. C. Wise, Developing and Assessing Students' Entrepreneurial Skills and Mind-Set, *Journal of Engineering Education*, **94**(2), 2005, pp. 233–243.
26. C. C. Fry and D. Pistrui, Assessing the Entrepreneurial

Mindset within Engineering Programs, in *American Society for Engineering Education*, 2011.
27. Q. Jin, S. K. Gilmartin, S. D. Sheppard and H. L. Chen, Comparing Engineering and Business Undergraduate Students' Entrepreneurial Interests and Characteristics, in *American Society for Engineering Education*, 2014.
28. D. Pistrui, J. K. Layer and S. L. Dietrich, Mapping the behaviors, motives and professional competencies of entrepreneurially minded engineers in theory and practice: An empirical investigation, in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2012.
29. N. Duval-Couetil, A. Shartrand and T. Reed-Rhoads, The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes, *Advances in Engineering Education*, **5**(1), 2016, pp. 1–27.
30. B. Johannisson, H. Landstrom and J. Rosenberg, University training for entrepreneurship–an action frame of reference, *European Journal of Engineering Education*, **23**(4), 1998, pp. 477–496.
31. N. Duval-Couetil, T. Reed-Rhoads and S. Haghighi, Engineering students and entrepreneurship education: Involvement, attitudes and outcomes, *International Journal of Engineering Education*, **28**(2), 2012, pp. 425–435.
32. D. Wilson, D. Jones, M. J. Kim, C. Allendoerfer, R. Bates, J. Crawford, T. Floyd-Smith, M. Plett and N. Veilleux, The Link between Cocurricular Activities and Academic Engagement in Engineering Education, *Journal of Engineering Education*, **103**(4), 2014, pp. 625–651.
33. S. M. Kusano and A. Johri, Student autonomy: Implications of design-based informal learning experiences in engineering, in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2014.
34. B. F. Willis, D. A. Willis and M. Fontenot, Developing leadership skills and creating community in engineering students, in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2014.
35. A. N. Rockenbach, M. J. Mayhew, S. Morin, R. Crandall and B. Selznick, Fostering the Pluralism Orientation of College Students through Interfaith Co-curricular Engagement, *The Review of Higher Education*, **39**(1), 2015, pp. 25–58.
36. M. E. Engberg, Educating the workforce for the 21st Century: A Cross-Disciplinary Analysis of the Impact of the Undergraduate Experience on Students' Development of a Pluralistic Orientation, *Research in Higher Education*, **48**(3), 2007, pp. 283–317.
37. B. A. Burt, D. D. Carpenter, C. J. Finelli, T. S. Harding, J. Sutkus, M. Holsapple, R. M. Bielby and E. Ra, Outcomes of engaging engineering undergraduates in co-curricular experiences, in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2011.
38. D. Carpenter and G. Feierfeil, Cultivating an entrepreneurial mindset through interdisciplinary collaboration and networking, in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2007.
39. A. W. Astin, Student involvement: A developmental theory for higher education, *Journal of College Student Development*, **40**(5), 1999, pp. 518–529.
40. A. W. Astin, *Assessment for excellence: the philosophy and practice of assessment and evaluation in higher education*, New York: Toronto: American Council on Education: Macmillan; Collier Macmillan; Maxwell Macmillan, 1991.
41. A. W. Astin, *What matters in college?: Four critical years revisited*, San Francisco: Jossey-Bass, 1993.
42. P. Terenzini and R. D. Reason, Parsing the First Year of College, in *Association for the Study of Higher Education*, 2005.
43. C. J. Finelli, M. A. Holsapple, E. Ra, R. M. Bielby, B. A. Burt, D. Carpenter, Donald, T. S. Harding and J. A. Sutkus, An Assessment of Engineering Students' Curricular and Co-Curricular Experiences and Their Ethical Development, *Journal of Engineering Education*, **101**(3), 2012, pp. 469–494.
44. National Academy of Engineering, The Engineering of 2020: Visions of Engineering in the New Century, National Academy Press, Washington, D.C., 2004.
45. D. B. Knight, L. R. Lattuca, E. W. Kimball and R. D. Reason, Understanding Interdisciplinarity: Curricular and Organizational Features of Undergraduate Interdisciplinary Programs, *Innovative Higher Education*, **38**(2), 2013, pp. 143–158.
46. B. Feld, Startup communities: building an entrepreneurial ecosystem in your city. John Wiley & Sons, Inc., Hoboken, New Jersey, p. xviii, 202 pages, 2012.
47. M. L. Fetter, P. G. Greene, M. P. Rice and J. S. Butler, Eds., *The Development of University-Based Entrepreneurship Ecosystems: Global Practices*. North Hampton, Massachusetts: Edward Elgar Publishing, Inc., 2010.
48. D. Chachra, H. L. Chen, D. Kilgore and S. Sheppard, Outside the classroom: Gender differences in extracurricular activities of engineering students, *Proceedings—Frontiers in Education Conference, FIE*, 2009, pp. 1–6.
49. Office of Innovation & Entrepreneurship, The Innovative and Entrepreneurial University: Higher Education, Innovation & Entrepreneurship in Focus, 2013.
50. M. W. Ohland, S. A. Frillman, G. Zhang, C. E. Brawner and T. K. Miller, III, The Effect of an Entrepreneurship Program on GPA and Retention, *Journal of Engineering Education*, **94**(4), 2004, pp. 293–301.
51. J. S. Long, Regression models for categorical and limited dependent variables. Sage Publications, Thousand Oaks, p. 297, 1997.
52. T. J. Bae, S. Qian, C. Miao and J. O. Fiet, The Relationship Between Entrepreneurship Education and Entrepreneurial Intentions: A Meta-Analytic Review, *Entrepreneurship Theory and Practice*, **38**(2), 2014, pp. 217–254.
53. A. B. Diekman, E. R. Brown, A. M. Johnston and E. K. Clark, Seeking congruity between goals and roles: a new look at why women opt out of science, technology, engineering, and mathematics careers, *Psychological science*, **21**(8), 2010, pp. 1051–7.
54. E. B. Tison, T. Bateman and S. M. Culver, Examination of the gender–student engagement relationship at one university, *Assessment & Evaluation in Higher Education*, **36**,(1), 2011, pp. 27–49.

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