Students Seeking Different Paths to Entrepreneurial Education

Prof. Sergio Celis P.E., Universidad de Chile

Sergio Celis is an Assistant Professor in the School of Engineering and Sciences at the Universidad de Chile. He conducts research on higher education, with a focus on teaching and learning in STEM fields. His primary research interest is in how multiple forces, internal and external to the institution, influence what and how we teach in colleges and universities. His doctoral thesis investigated how social and intellectual movements influenced the emergence of entrepreneurship education in engineering. Sergio received his professional degree in industrial engineering at the University of Chile and his Ph.D. in higher education at the University of Michigan.

Dr. Aileen Huang-Saad, University of Michigan

Aileen is an Associate Professor of Practice in Entrepreneurship and Biomedical Engineering. Previously, Aileen was the Associate Director for Academics in the Center for Entrepreneurship and was responsible for building the Program in Entrepreneurship for UM undergraduates, co-developing the masters level entrepreneurship program, and launching the biomedical engineering graduate design program. Aileen has received a number of awards for her teaching, including the Thomas M. Sawyer, Jr. Teaching Award, the UM ASEE Outstanding Professor Award and the Teaching with Sakai Innovation Award. Prior to joining the University of Michigan faculty, she worked in the private sector gaining experience in biotech, defense, and medical device testing at large companies and start-ups. Aileen's current research areas include entrepreneurship engineering education, impact and engaged learning. Aileen has a Bachelor's of Science in Engineering from the University of Pennsylvania, a Doctorate of Philosophy from The Johns Hopkins University School of Medicine, and a Masters of Business Administration from the University of Michigan Ross School of Business. Aileen is also a member of Phi Kappa Phi and Beta Sigma Gamma.

Students Seeking Different Paths to Entrepreneurial Education

Introduction

Science and technology innovation is the economic driver of the future. In response to this and a call from the National Academies to actively provide the infrastructure and resources to support the education of the best and brightest science, math and engineering students[1], several higher education engineering institutions are now turning towards entrepreneurship education as a mechanism for educating innovators of tomorrow[2,3]. Consensus on the appropriate structure, implementation and core skills of entrepreneurship education is still up for debate[4,5].

Entrepreneurship education has evolved since it was first taught in business schools in the mid-1940s. As it continues to be incorporated across disciplines, entrepreneurship education has seen a number of innovations and has benefited from advances in student learning[6]. Entrepreneurship education has expanded well beyond single business plan classes. Recently, engineering colleges have been the most aggressive at incorporating entrepreneurship at different levels, from individual course development, certificate creation, to program development[3,4,7]. In 2010, over 50% of ASEE engineering programs offered entrepreneurship opportunities to their students and approximately 25% had a more structured opportunity, such as a minor[7]. While the curriculum and delivery varied, Gilmartin et al. (2014)[3] found that entrepreneurship program goals addressed a number of skills and outcomes, including "helping students to develop an entrepreneurial mindset, promoting understanding of technology commercialization, building leadership skills in an entrepreneurial context, and supporting venture creation" (p. 11). Pedagogical strategies were also similar, deploying many strategies already actively used in the engineering classroom, including experiential learning and problem based learning. Many engineering programs also augmented their curricula by offering co-curricular entrepreneurship experiences, allowing students to put entrepreneurial skills into practice, such as competitions or mentorship[7]. Often, these co-curricular experiences were used to offer students entrepreneurship education while addressing the concern that there was a limited availability for electives in engineering curriculum[4].

As these new entrepreneurship programs continue to thrive and innovatively develop across engineering colleges, there is value to deconstructing the entrepreneurship education students experience to better understand the impact of such comprehensive programs not only as a research question but also for more effective administration. Based on the Terenzini and Reason's (2005)[8] conceptual framework for studying college impact, we propose that there are multiple influences that impact engineering students in engineering entrepreneurship education, including the student's pre-college characteristics, the organizational context, and the students' personal experiences. Due to the relatively nascent nature of engineering entrepreneurship education, few studies have been performed to evaluate the impact of student characteristics and their participation in entrepreneurship opportunities outside of the classroom. This paper is an exploratory study to examine relationships between student characteristics (e.g., gender and academic performance) and entrepreneurship education programmatic choices (e.g., curricular and co-curricular) on students in a single Midwest research institution.

Review of the literature

Student Differences and Student Participation in Entrepreneurship Programs

This study investigates the socio-demographic and academic differences between students enrolled in an entrepreneurial curricular experience and those who only participated in entrepreneurial co-curricular experiences. Unfortunately, there are few studies that both describe an entrepreneurship education program and report student data (e.g., participation, learning outcome assessments) or study some entrepreneurial construct (e.g., entrepreneurial intent) with student data from existing engineering or entrepreneurship programs. Most studies that collect student data assess entrepreneurial intent[9,10] to discover the underlying relationship between intention, participation, and skills (e.g., leadership, creative thinking)[11–16] or investigate the impact of entrepreneurship education on student outcomes (e.g., retention)[17–19]. However, with notable exceptions[20,21], these studies do not consider students' socio-demographic characteristics to evaluate or assess programs.

Much can be gained by considering socio-demographic characteristics, as numerous empirical studies in higher education show that these characteristics, such as gender, race, and pre-college academic preparation affect students' college experience[22]. A notable exception is Duval-Couetil et al's. (2012)[20] multi-institutional study of engineering capstone courses. Duval-Couetil et al. (2012)[20] 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. Other studies, with a shorter list of student characteristics, have reported different results. Jin et al. (2014)[21] 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)[18] reported that while females were substantially underrepresented in a specific engineering entrepreneurship program, active recruiting increased the number of female participants. In contrast, Bilén et al. (2005)[11] reported that a minor in entrepreneurship enrolled a significantly higher proportion of women than the existing proportion of women 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.

Co-curricular Involvement in Engineering and Entrepreneurship Education

The value and impact of co-curricular experiences in the context of engineering education has been a growing topic of research for several years. Co-curricular experiences have been shown to increase student engagement [23], enhance self-directed autonomy [24], nurture leadership[25] and enrich ethical decision making [26]. The consistent positive impact findings suggest that co-curricular entrepreneurship education also has the potential to add significant value to students. The deliberate use of informal activities in entrepreneurship education demands a more 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 present 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[20,27,28], these experiences are often clustered together with little analysis of structure, levels of institutional support, or levels of student participation, or. For instance, Duval-Couetil et al. (2012)[20] 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)[20] 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)[29] 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)[27] mentioned "embedding entrepreneurship beyond the classroom" as a strategy for "expanding the learning experience without additional credit hours." Among these experiences, the author 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 socio-demographic characteristics and simplify the conceptualization of co-curricular experiences, suggesting a vague alignment with the curriculum.

Conceptual Framework

In an effort to work towards a more structured approach to studying the complexities of engineering entrepreneurship education and its impact on students in higher education, we have chosen to position this analysis in the context of Lattuca et al.'s (2014)[30] use of the Terenzini and Reason conceptual framework[8] for studying college impact. The framework was the result of a two-year national research and development initiative to better understand how multiple and interconnected factors influence student academic success and perseverance, leveraging over 35 years of higher education research.

Terenzini and Reasons' college impact model attempts to integrate the complexities of the student college experience. Their comprehensive model is a conceptual map that suggests college influences on students are not singularly important, but it is the interconnection of influences that most impact student outcomes (learning, development, change and persistence). Their model suggests causal connections between and among these influences. According to their model, there are three primary influences on student outcomes: student pre-college characteristics and experiences, organizational context and peer environment (Table 1).

Table 1: Terenzini and Reason Conceptual Framework of College Impact: Primary Influences in Student Learning (adapted from Terenzini and Reason (2005)[8].

Primary Influence	Examples
Student Pre-college Characteristics and Experiences	Socio-demographic traits Academic preparation and performance Personal and social experiences
Organizational Context	Internal structures, policies and practices Academic & co-curricular programs, policies & practices Faculty culture
Peer Environment (Individual Student Experiences)	Classroom Experiences Out-of-class Experiences Curricular Experiences

An application of the Terenzini and Reason model in engineering education can be found in Lattuca et al.'s (2014) [30] studies benchmarking undergraduate engineering education in the United States and evaluating how engineering programs resonate with and are progressing towards goals of the National Academy of Engineering Engineer of 2020[31]. Both studies leveraged the Terenzini and Reason model such that survey questions and interview protocols mapped onto the framework, exploring how pre-college characteristics shape engineering student engagement with various aspects of the home institution. With regard to promoting students' interdisciplinary skills and contextualization, Lattuca et al. (2014) specifically identified the need for engineering schools to take advantage of the co-curricular activities and the role they can play in developing engineer 2020 competencies. As noted by Lattuca et al. (2014) *"Engineering schools and programs should consider how to leverage co-curricular activities, particularly community service and humanitarian engineering projects, by creating intentional linkages between the formal curriculum (e.g. developing global awareness) and these informal learning experiences (e.g. engineering-related study abroad). Such linkages may be particularly effective in helping develop students' contextual awareness."*

As engineering entrepreneurship education takes shape and continues to leverage co-curricular experiences for learning, Lattuca et al.'s findings suggest that a more in depth analysis of entrepreneurial co-curricular experiences in the context of the Terenzini and Reason's college impact framework is warranted. There is an organizational reliance on both entrepreneurship academic and co-curricular programs, required active learning classroom experiences, and individual exposure to the entrepreneurial culture developed by students, faculty and staff at universities. In particular, numerous *beyond the classroom* experiences have emerged from entrepreneurship education initiatives (e.g., study trips, student startup accelerators, and pitch competitions) along with more structured academic plans (e.g., certificates, minors)[3]. This makes it possible to distinguish between a curricular and a co-curricular path to entrepreneurship education in engineering. Although these paths co-exist in numerous academic environments, as shown in our literature review, the co-curricular path is diverse and ill defined and little is known about what type of students are attracted to these paths and how they differ from each other. This paper begins to deconstruct engineering entrepreneurship education to explore the primary influences on student learning. In this paper, we look to examine the front end of the Terenzini

and Reason conceptual framework, do differences in pre-college characteristics affect the student learning pathway, curricular versus co-curricular as defined by the following co-curricular construct.

The term co-curricular captures a wide range of learning experiences available to students that complements their academic program. In some instances, co-curricular experiences are defined by a separation from academic courses, administered by outside organizations, or offered outside of the academic calendar for varying durations. This broad definition introduces a challenge when trying to capture the impact of specific programmatic aspects of a co-curricular experience. Thus, in the context of this paper, we believe it is necessary to specifically define entrepreneurial co-curricular experiences as student, self-selected, non-credit bearing entrepreneurship experience that can be characterized by two different variables, level of institutional support and level of student engagement. Institutional support includes, instructional, administration, and financial. Level of student engagement represents the level of student commitment (e.g., hours of participation, persistence) towards the activity.

In this study, we attempt to rigorously look at the student participation in curricular and co-curricular entrepreneurship experiences. In an attempt to control for the diversity of opportunities available to entrepreneurship students, we selected to study students involved in a single institution entrepreneurship program that have the option to participate in two co-curricular activities with high levels of institutional support and varying levels of 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.

Entrepreneurial Site and Data Collection

Data was collected from an entrepreneurship program anchored in a large, Midwest, public research university college of engineering center for entrepreneurship (CFE). The CFE was developed in response to student, alumni, faculty and administrative demands to address the needs of educating engineering students for the changing economy. Both curricular and co-curricular experiences were supported by the CFE (Table 2) at different levels (i.e., staff, training, funding, mentorship, etc.). Curricular experiences included individual entrepreneurship classes and a formal 9-credit certificate program, designated the Program in Entrepreneurship. The formal Program in Entrepreneurship required students to enroll in a collection of entrepreneurship of courses, including a seminar, core entrepreneurship course, elective and capstone practicum courses. Both the seminar and capstone courses were administered by the CFE. The core and elective courses leveraged course offerings across the university. The program was available to all students on the university campus. Interested students could declare the Program in Entrepreneurship any time after their freshman year. The framework for the Program in Entrepreneurship served as a model for the campus wide minor in entrepreneurship, launched in the Fall of 2014.

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

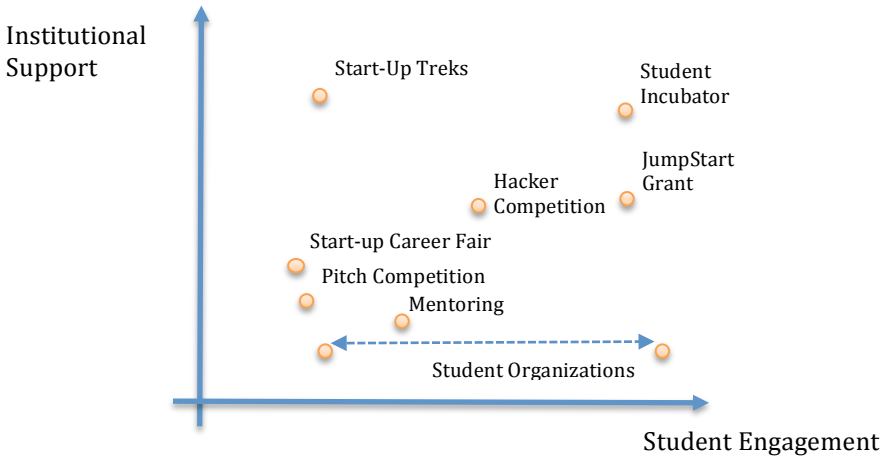
administered programs included a start-up fund to support student entrepreneurial initiatives, start-up trek's to Silicon Valley and other entrepreneurial urban centers, an annual pitch competition, a student incubator and mentoring (Table 2, Figure 1). CFE also was involved in other activities that required lesser level of institutional support. For instance, CFE coordinated numerous mentors, who interacted frequently with students, and supported a diverse array of student entrepreneurial organizations.

For this study, we only used co-curricular data from students participating in the start-up treks and the student incubator because these programs were the two co-curricular experiences that required the most institutional support and had different levels of student engagement. The high level of institutional support included faculty instruction, using entrepreneurship curriculum that was consistent with that used in the Program for Entrepreneurship, program coordination and execution, mentorship facilitation, and financial support. The high level of institutional support 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, the CFE documented which students declared the Program in Entrepreneurship. 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 was limited to undergraduate students, as the program was targeted yet not limited to undergraduates.

Table 2: Curricular and Co-curricular Experiences Offered by the Center for Entrepreneurship

Curricular (for credit)	Co-Curricular (not for credit)
Individual Classes	Provost Funded Jump Start Grant
9-credit Program in Entrepreneurship	Start-Up Trek's
	Pitch Competitions
	Student Incubator
	Mentoring
	Start-up Career Fair
	Student Entrepreneurial Organizations

Figure 1. Co-Curricular Experiences Supported by the Center for Entrepreneurship.



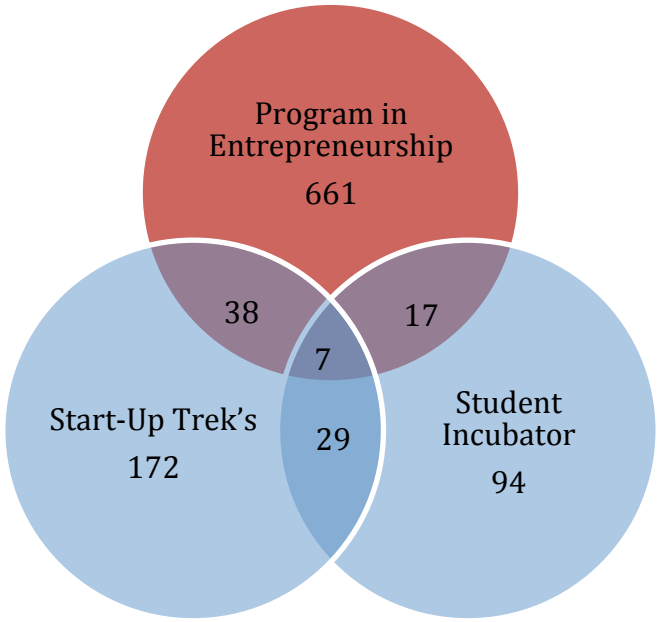
Descriptive Statistics

Overall, our data consists of institutional records of 1,018 undergraduate students who participated in these curricular and co-curricular activities over the past seven years (2007-2013). Table 3 summarizes the descriptive statistics of our sample. Of this sample, 723 students enrolled in the certificate (71%), 357 participated in at least one of the two co-curricular programs organized by CFE (36%), and 62 participated in both curricular and co-curricular activities (6%). Figure 2 depicts a Venn diagram of student participation in these three programs.

Table 3: Descriptive Statistics (N =1,018)

	N	%
Student Participation in entrepreneurial activities:		
Curriculum		
Program in Entrepreneurship	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	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

Figure 2: Venn's Diagram of Student Participation in Entrepreneurial Activities



Analysis

Multiple univariate analysis was used to test differences among groups. Chi-squared tests were used to tests differences in the distribution of participation. We also conducted t-tests to compare mean differences in GPA (at their first semester and the cumulative GPA in the last semester enrolled in the institution) between students enrolled in the curricular program and those who only participate in co-curricular activities. Aggregated information of students who enrolled in different years present a challenge to the analyses. For instance, this creates what is called left-censoring data (Box-Steffensmeier, 2007). This means that a group of students are still enrolled in the institution, making it possible for them to still enroll in the curricular program or participate in the co-curricular activities if they have not done so by the time data was collected. This might introduce some bias into our analyses. However, most of our sample completed their undergraduate education, and when possible, we repeated the tests with different sub-samples in order to assess the influence of censored data.

Results

Our findings indicated differences between students who enrolled in the curricular program and those who participated in the two specific co-curricular programs organized by the CFE. Table 4 summarizes the distribution of students in these programs by socio-demographic characteristics and academic performance. In our sample, gender appeared to be a key factor in determining the type of participation in entrepreneurship activities. Female students represented 32% of the undergraduate population enrolled in the curricular program. In contrast, female students were only 22% of the co-curricular population. In terms of academic majors, according to the major students enrolled in their first semester at the institution, engineering students participated in greater proportion in the co-curricular activities (53%) than in the curricular program (32%), even despite the fact that both curricular and non-curricular programs were open to all university students. Other student characteristics were not statistically different. The same

proportion of international students participated in both types of programs (10% approx.). Similarly, among US citizens and permanent residents, underrepresented minority students also participated at the same rate (10% approx.) in both types of programs. Chi-squared tests were also conducted to test differences between those who participated the in Start-Up Treks and the Student Incubator. We found no significant difference between the participants in these two co-curricular activities, which validated the strategy of clustering Start-Up Trek's and Student Incubator into the co-curricular category.

Table 4: Distribution and Means of Student Participation in Curricular and Co-curricular Paths

	Curricular[a]		Co-curricular (only)			
	N	%	n	%	diff. (%)	P
Female	228	32%	66	22%	10%	<.01
International	78	11%	22	7%	4%	.105
Underrepresented minority (urm)	63	10%	26	10%	0%	.909
Engineering major	233	32%	157	53%	-21%	<.001
	Mean	Sd	mean	sd	diff.	
Initial GPA - first semester	3.21	0.52	3.36	0.47	-0.15	<.001
Cumulative GPA - last semester	3.24	0.87	3.58	1.65	-0.34	<.001

Notes: [a] The column for the curricular path includes the 62 students who participated in both curricular and co-curricular activities.

Since the greater concentration of engineering students in co-curricular programs could explain the participation gender gap, we also explored gender distribution among engineering students in our sample. Even though female engineering students participated at a greater rate in the curricular program (21%) than in co-curricular ones (17%), the difference was not statistically significant. When the same analyses was conducted with the non-engineering population, the gender difference became borderline significant (37% vs. 28%, Chi2= 3.2492, p <0.1).

Results also suggested differences in academic performance prior to enrolling in the institution. The t-test indicated that students who only participated in co-curricular programs had a greater GPA (3.36) than their counterparts (3.21). Although modest, the mean difference was still statistically significant (t(1016)= -4.2656, n= 1,018, p<0.001). This difference in academic performance translated to university performance. When the t-test was conducted on the cumulative GPA, considering the last semester registered for each student by 2013, students who only participated in co-curricular programs had a greater cumulative GPA (3.58) than their counterparts (3.24). (t(1016)= -4.1891, n= 1,018, p<0.001).

Discussion and Conclusion

With entrepreneurship education being used as a major effort to develop the innovative workforce of tomorrow in engineering institutions, it is imperative that institutions become cognizant of how the programs they develop impact student outcomes and attract a diverse group of students. Over the last several years, engineering entrepreneurship programs are clearly

evolving to be comprehensive educational experiences that rely on curricular and co-curricular experiences. In this study, we begin to explore the impact of entrepreneurship curricular opportunities (curricular versus co-curricular) on engineering students with respect to gender, international status, race, major, and pre-college academic performance.

Based on our findings, we found that a larger percent of women participate in entrepreneurship curricular programs than co-curricular programs. This finding has several potential implications. Given the nascent state of the field of entrepreneurship education research, there is very limited research published regarding gender and entrepreneurship education. Based on a SCOPUS search on October 26, 2014, there have only been 633 published papers that address entrepreneurship and gender since 1988. Only 103 of the 633 papers address gender and education, yet none address the influence of the pedagogy used on gender. The papers address entrepreneurial intent and treatment affects of diverse programs across institutions on large numbers of students. Nonetheless, our finding and several sociological findings suggest that a deeper evaluation of entrepreneurship education in relation to gender is worthy of further investigation. 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 programs, institutions, curricula and pedagogy. These studies offer limited insight into the influence of gender on entrepreneurship education sharing a common curriculum.

We also found that there is no difference in international and 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)[11] 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. It may be the case that the difference in pre-college GPA is a simple artifact of the greater participation of engineering students in the co-curricular programs. Further multivariate analyses might clarify this issue. Another alternative 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. In a following study, we will test variations of GPA by semester and the effect on GPA on the entrepreneurship education path and vice-versa.

Results reported here is just the beginning of a broader initiative to deconstruct the engineering entrepreneurship educational experience. Ultimately, these results will play a significant role in helping engineering faculty and staff develop and prioritize their

entrepreneurial programs to effectively maximize student entrepreneurial outcomes for all students of all socio-demographics.

References

1. National Academy of Sciences, N. A. of E. I. of M. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. (2007).

2. Byers, T., Seelig, T., Sheppard, S. & Weilerstein, P. Entrepreneurship Its Role in Engineering Education. *Bridg.* (2005).

3. Gilmartin, S., Shartrand, A., Chen, H., Estrada, C. & Sheppard, S. Programs for Undergraduate Engineers. (2014).

4. Standish-Kuon, T. & Rice, M. P. Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities. *J. Eng. Educ.* 33–39 (2002).

5. Mars, M. & Metcalfe, A. S. The entrepreneurial domains of American Higher Education. *ASHE High. Educ. Rep.* **34,** (2009).

6. Katz, J. a. The chronology and intellectual trajectory of American entrepreneurship education 1876-1999. *J. Bus. Ventur.* **18,** 283–300 (2003).

7. Shartrand, A., Weilerstein, P., Besterfield-Sacre, M. & Golding, K. Technology Entrepreneurship Programs in U.S. Engineering Schools: Course and Program Characteristics at the Undergraduate Level. in *American Society for Engineering Education* (2010).

8. Terenzini, P. & Reason, R. D. Parsing the First Year of College. in *Association for the Study of Higher Education* (2005).

9. Luthje, C. & Franke, N. the 'making' of an entrepreneur: testing a model of entrepreneurial intent among engineering students at MIT. *R D Manag.* **33,** 135–147 (2003).

10. Souitaris, V., Zerbinati, S. & Al-Laham, A. Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources. *J. Bus. Ventur.* **22,** 566–591 (2007).

11. Bilén, S. G., Kisenwether, E. C., Rzasa, S. E. & Wise, J. C. Developing and assessing students' entrepreneurial skills and mind-set. *Journal of Engineering Education* **94,** 233–243 (2005).

12. Fry, C. C. & Pistrui, D. Assessing the Entrepreneurial Mindset within Engineering Programs. in *American Society for Engineering Education* (2011).

13. Jin, Q., Gilmartin, S. K., Sheppard, S. D. & Chen, H. L. Comparing Engineering and Business Undergraduate Students' Entrepreneurial Interests and Characteristics. in *121st ASEE Annual Conference & Exposition* (2014).

14. Pistrui, D., Layer, J. K. & Dietrich, S. L. 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).

15. Duval-Couetil, N., Shartrand, A. & Reed-Rhoads, T. The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes. *Adv. Eng. Educ.* (In Press)

16. Johannisson, B., Landstrom, H. & Rosenberg, J. University training for entrepreneurship--an action frame of reference. *Eur. J. Eng. Educ.* **23,** 477–496 (1998).

17. Green, J. V. Bringing a technology entrepreneurship curriculum online at the University of Maryland. in *ASEE Annual Conference and Exposition, Conference Proceedings* (2011).

18. Ohland, M. W., Frillman, S. A., Zhang, G., Brawner, C. E. & Miller, III, T. K. The Effect of an Entrepreneurship Program on GPA and Retention *. *J. Eng. Educ.* (2004).

19. Radharamanan, R. Developing innovation skills and assessing student learning at MUSE. in *ASEE Annual Conference and Exposition, Conference Proceedings* (2012).

20. Duval-Couetil, N., Reed-Rhoads, T. & Haghighi, S. Engineering students and entrepreneurship education: Involvement, attitudes and outcomes. in *International Journal of Engineering Education* **28,** 425–435 (2012).

21. Jin, Q., Gilmartin, S. K., Sheppard, S. & Chen, H. L. Comparing Engineering and Business Undergraduate Students' Entrepreneurial Interests and Characteristics Comparing Engineering and Business Undergraduate Students ' Entrepreneurial Interests and Characteristics. in *American Society for Engineering Education* (2014).

22. Pascarella, E. T. & Terenzini Patrick T. *How College Affects Students: A Third Decade of Research*. (2005).

23. Wilson, D. *et al.* The Link between Cocurricular Activities and Academic Engagement in Engineering Education. *J. Eng. Educ.* **103,** 625–651 (2014).

24. Kusano, S. M. & Johri, A. Student autonomy: Implications of design-based informal learning experiences in engineering. in *ASEE Annual Conference and Exposition, Conference Proceedings* (American Society for Engineering Education, 2014).

25. Willis, B. F., Willis, D. A. & Fontenot, M. Developing leadership skills and creating community in engineering students. in *ASEE Annual Conference and Exposition, Conference Proceedings* (American Society for Engineering Education, 2014).

26. Burt, B. A. *et al.* Outcomes of engaging engineering undergraduates in co-curricular experiences. in *ASEE Annual Conference and Exposition, Conference Proceedings* (2011).

27. Carpenter, D. & Feierfeil, G. Cultivating an entrepreneurial mindset through interdisciplinary collaboration and networking. in *ASEE Annual Conference and Exposition, Conference Proceedings* (2007).

28. Jin, Qu, Gilmartin Shannon Katherine, Chen, H. L. Comparing Engineering and Business Undergraduate Students ' Entrepreneurial Interests and Characteristics Comparing Engineering and Business Undergraduate Students ' Entrepreneurial Interests and Characteristics. *121st ASEE Annu. Conf. Expo.* (2014).

29. Jin, Q., Gilmartin, S. K., Sheppard, S. D. & Chen, H. L. Comparing engineering and business undergraduate students' entrepreneurial interests and characteristics. in *ASEE Annual Conference and Exposition, Conference Proceedings* (American Society for Engineering Education, 2014).

30. Lattuca, L. R., Terenzini, P. T. & Knight, D. B. *2020 Vision : Progress in Preparing the Engineer of the Future*. 1–59 (2014). at <http://deepblue.lib.umich.edu/handle/2027.42/107462>

31. National Academy of Engineering. *The Engineering of 2020: Visions of Engineering in the New Century*. 238 (National Academy Press, 2004).