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Investigating Entrepreneurship Program Models in Undergraduate Engineering Education*

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Major private and government organizations in the U.S. are promoting entrepreneurship education for undergraduate students, including engineers. Different configurations of entrepreneurship learning opportunities have emerged, not all within or in partnership with schools of business. There is some uncertainty about how entrepreneurship programs targeted to engineers are structured, with what purpose and pedagogical approaches. This study is designed to address uncertainty about entrepreneurship learning opportunities for undergraduate engineers and examine facets of formal engineering entrepreneurship programs. Our study considers the histories, missions, and pedagogies of these programs. We conducted in-depth interviews with program directors at 12 entrepreneurship programs across the U.S., and then coded the interview transcripts in a two-stage, collaborative process. Our findings show that entrepreneurship programs for engineers often are designed to provide business education in light of otherwise limited opportunities for formal, classroom-based business and entrepreneurship learning. Student demand is key to program growth; available faculty resources can pose a challenge. Programs vary in terms of goals around venture creation, types of interactions with students from other disciplines, and even how "entrepreneurship" itself is defined. Pedagogical features include experiential learning and hands-on activities, and self-directed learning environments that promote tolerance for ambiguity and failure. Implications for assessment of student outcomes, new program development, educational research, and engineering education as a whole are discussed.

Keywords: engineering entrepreneurship programs; entrepreneurship education; program design; entrepreneurship learning outcomes

1. Introduction

Entrepreneurship is an increasingly salient topic in higher education. Multiple groups have brought entrepreneurship to the forefront of university and college agendas: educators who want to provide students with new platforms for thinking both practically and creatively, students who want to push the boundaries of traditional curricula and engage in real-world enterprise, and institutions and regions that want to see economic value emerge from student and faculty innovation. In the U.S., the Kauffman Foundation is well known for its support of entrepreneurship initiatives and research; its report *Entrepreneurship Education Comes of Age on Campus* [1] documents both the groundswell of interest in entrepreneurship education as well as its challenges, such as lack of clarity surrounding measurable outcomes. Federal agencies are on the scene as well—in 2013, the U.S. Department of Commerce published *The Innovative and Entrepreneurial University: Higher Education, Innovation & Entrepreneurship in Focus* [2], which profiles entrepreneurship programs at campuses around the country.

Administrative "ownership" of entrepreneurship education on campus varies, despite its high visibility; institutions are experimenting with different forms [1]. Business schools, long the site where one might expect to find entrepreneurship education, include entrepreneurship topics in their curricula, but these topics are often perceived as outside of the "core" business disciplines and can get "short shrift" [3, p. 144]. At some campuses, students from any field can theoretically enroll in a business-based entrepreneurship course, although this is by no means the case everywhere. Different configurations have emerged to deliver entrepreneurship

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education outside of business schools, ranging from decentralized administrative units (e.g., entrepreneurship offered in both schools of business and engineering) to centralized, multidisciplinary entrepreneurship education managed out of senior administrative offices [see 4].

Simultaneously, a focus on entrepreneurship education targeted to engineering students is on the rise, in concert with calls for engineers to have entrepreneurial know-how, understanding of what it means to "innovate," and competency in problem-framing, not only problem-solving [5–7]. Shartrand, Weilerstein, Besterfield-Sacre, and Golding [8] identified 47 stand-alone technology entrepreneurship programs for engineering undergraduates at U.S. campuses as of 2008. It is likely that this number has increased in the years since. Concurrently, a small (and growing) group of engineering education researchers has studied entrepreneurship learning contexts for engineers [e.g., 4, 9–11], convening via specialized conference divisions, journals, and focused meet-ups [12–15].

Yet amidst increasing interest in entrepreneurship education and proliferation of stand-alone programs, a good deal of uncertainty and ambiguity remain about how entrepreneurship programs for engineers actually work—the nuts and bolts of an entrepreneurship education program, so to speak. (*If* they work is a separate question—treated by Ohland, Frillman, Zhang, Brawner, and Miller [10] and other single-case program assessments.) Questions have emerged around the *origins* of these programs for engineers, the *missions* of these programs, and the *pedagogies* of these programs, in effort to better understand and articulate engineering student outcomes in such programs, and identify the role of these learning opportunities in engineering (and higher) education more generally. Uncertainty surrounding entrepreneurship program development, in addition to skepticism about the importance of entrepreneurship education for engineers, might help to explain why some engineering faculty have doubts about emphasizing entrepreneurship in engineering learning environments [see 16–17].

In order to address this uncertainty, the current study spotlights U.S. entrepreneurship programs for undergraduate engineers and probes program histories, missions, and pedagogies across a multi-institution sample. This is a qualitative and descriptive study to bring program design into full view, and define and map models from creation to operation. The research questions that guide this study are:

1. How do formal entrepreneurship education programs for undergraduate engineers get started (especially within schools of engineering), and how do they grow? Which contextual characteristics appear to influence growth?
2. What are the educational missions of such programs? How do these programs define "entrepreneurship" and related concepts?
3. What are the pedagogical features of such programs, and how are these similar to or different from other types of engineering pedagogies?
4. To what extent can we identify a model (or models) of formal entrepreneurship learning opportunities for undergraduate engineers in the U.S.?
5. What are the implications of our findings for assessment of student outcomes, new program development, educational research, and engineering education as a whole?

Findings from this study also can inform hypotheses for larger-scale studies of the effects of entrepreneurship learning opportunities and contexts on engineering student outcomes.

Stepping back, entrepreneurship education exemplifies new learning environments for engineers that are generating thoughtful conversations, critique, and curiosity among educators, in the U.S. and around the world [see 16, 18, 19]. The detail on entrepreneurship programs in this paper can inform these broader conversations about essential undergraduate experiences for the rising generation of global engineers.

2. Background of the Study

2.1 Foundational papers

Studies of entrepreneurship programs for engineers often draw from single-case descriptions or evaluations [e.g., 10, 20]. Research probing for program goals and histories across a multi-program sample, i.e., where programs are the primary unit of analysis from which to make broader statements about this type of engineering learning environment, is less common. Literature reviews of best practices in engineering education have been published [e.g., 21], although these tend not to be in the area of engineering entrepreneurship and innovation. Solomon has been conducting surveys of the entrepreneurship landscape at U.S. colleges and universities for three decades, but these surveys are not specific to engineering schools' approaches to entrepreneurship [22, 23]. Similarly, Vesper's work [24, 25] provided an early precedent for studying entrepreneurship education in the academy, although again this was not specific to engineering.

However, four studies published since 2002 have analyzed entrepreneurship programs for engineers using multi-program samples, treating the program

as either the primary unit of analysis or a grouping variable in a multi-institution study of students. Our study is informed by these four papers on entrepreneurship program designs and approaches, which we summarize below. These four studies are not alone in providing insights into entrepreneurship program structures in a way that is abstracted from single case assessments [e.g., 11, 26, 27]. But they are among the few studies that delve directly into a classification of program characteristics, and help to build a picture of the "state" of entrepreneurship programming for engineers.

In their study of six U.S. institutions, Standish-Kuon and Rice [28] first identified three models of delivering formal, curriculum-based entrepreneurship education to science and engineering students: programs located in schools of business (characterized by collaboration with engineering partners and/or encouragement of engineering student participation); programs located within schools of engineering (characterized by "growing cross-pollination" with business school offerings); and programs located across schools (a "multi-school" model—characterized by curricula jointly developed by a business school and a technical school). Notably, the authors stressed that these models are dynamic entities—over the duration of their study, one school had moved from a business-based model to a multi-school model, with a second indicating movement in the opposite direction.

Later, Shartrand et al. [8] presented the results of the first comprehensive classification of formal technology entrepreneurship programs at almost 350 engineering schools in the U.S. as of 2008. Programs, defined as "any set of courses or experiential activities that are sponsored by the university to promote student awareness of and competence in entrepreneurial thinking and practice," (p. 5) were identified by searching the course catalogs of U.S.-based American Society of Engineering Education (ASEE) member institutions for programs of study whose titles and descriptions contained the keyword of "entrepreneurship," or related keywords, such as "innovation," "enterprise," and "venture." Programs that were listed or cross-listed in engineering departments, colleges, or schools were included, as were programs that focused explicitly on technology-based entrepreneurship with documented pathways for engineers to participate. The authors identified 47 undergraduate entrepreneurship programs at 45 institutions that focused on technology- or engineering-based entrepreneurship. Of these 47 programs, most were described as minor, certificate, or concentration programs, and just over half were located within schools of engineering.

Building on Shartrand et al.'s [8] work and sample, Besterfield-Sacre, Ozaltin, Shartrand, Shuman, and Weilerstein [9] described how undergraduate entrepreneurship programs offered through 38 engineering schools clustered on several qualitative and quantitative dimensions, including: degree of an engineering school's involvement in entrepreneurship (what the authors refer to as "density"), number of physical spaces for entrepreneurial learning, institutional type, and (in a separate cluster analysis) types of entrepreneurship courses available. These clusters indicated that entrepreneurship programming can take place in a wide range of contexts, and sometimes in very low-density engineering entrepreneurship environments. However, the majority of programs in the sample were located at doctoral-granting universities. The mix of courses offered in these programs varied (and clustered) as well, although most of the clusters showed only low to moderate offerings for courses on "Becoming and Being an Entrepreneur" (with more tending to focus on "Product Ideation and Development").

Most recently, Duval-Couetil, Shartrand, and Reed [4] examined entrepreneurship program models in the context of engineering student outcomes. First, the authors proposed factors that influence university-based program model development, inclusive of "administration," "environment," "pedagogy," and "people." Their subsequent comparison of engineering students' survey responses across three institutions with different entrepreneurship models (two, engineering-based, and one, "multi-disciplinary") showed that students in the multi-disciplinary model report higher levels of entrepreneurship knowledge and confidence than do students in the engineering-based model. This paper relates to Duval-Couetil's earlier studies of entrepreneurship program assessment [29] and innovation education programs [30], both of which take a program-level view on educational opportunities for students to learn about entrepreneurship and innovation.

2.2 Our prior work

Together these studies set the stage for our research, which was conceived as "rounding out" understanding of programmatic opportunities for engineers to learn about entrepreneurship, and paving the way towards a more expansive understanding of program models. Our larger research project had two components [31]. The aim of the first component was to collect basic quantitative data (e.g., demographics of students and faculty) on U.S. entrepreneurship programs for undergraduate engineers. These data, drawing from an 18-program sample, indicated that the majority of entrepreneurship programs housed in engineering were open to non-engineering students, and the numbers of engi-

neering and non-engineering undergraduate participants varied widely. Consistent with U.S. degree attainment rates by field, mechanical engineering majors composed the largest proportion of undergraduate engineering participants; non-engineering student participants often came from economics, finance/business, or psychology fields. The median proportion of women engineers among undergraduate engineering participants was 23 percent. Programs tended to have a majority of non-tenure-line faculty or a mix of tenure- and non-tenure-line faculty at the helm (rather than a majority of tenure-line faculty); although one program had 18 engineering faculty members involved in program delivery, the median number of participating engineering faculty was five. A little under half of the programs reporting faculty demographic data (5 of 14) did not have any women faculty involved in program delivery.

These very basic program characteristics provided important background for our project's second, deeper component: a qualitative investigation into program histories, missions, and pedagogies, domains not covered in Standish-Kuon and Rice [28], Shartrand et al. [8], Besterfield-Sacre et al. [9], and Duval-Couetil et al. [4]. The present paper summarizes the findings from this second component.

2.3 Theoretical considerations

Our research questions are largely exploratory and conceived as an extension to previous empirical work on programmatic contexts. However, we draw on Tolbert, David, and Sine's [32] discussion of institutional theory and entrepreneurship research to help us think about the potential influence of entrepreneurship beliefs on the programmatic offerings for students—and our limits in identifying this influence. Institutional theorists probe the effect of shared norms, values, and beliefs at the institutional, or social structural, level on organizational practice. Tolbert et al. demonstrate how such institutional dynamics frame and guide entrepreneurial actions, and how entrepreneurial actions bear on institutional change. To some extent, entrepreneurship programs for engineers embody or result from these shared norms, values, and beliefs in colleges and universities. Yet in our study, because our primary unit of analysis *is* the program, at a given point in time, we miss many beliefs that legitimate such a program to begin with. That is, we are able to gather program directors' beliefs and historical narratives, as they are the chief informants for each program in this study, but we only have an indirect window onto other belief systems at play (e.g., the beliefs of past and present senior university administrators, faculty beliefs about entrepreneurship, the beliefs of alumni donors, the narratives and norms of firms in surrounding regions). We also are limited by our cross-sectional design in disentangling beliefs from structure, which constrains attributions of impact to certain structural features (i.e., is it the structure that has the effect, or the beliefs driving and rationalizing it?).

Moreover, in considering only institutional pressure on entrepreneurial outcomes, we risk adopting an "overly determined" view of institutional dynamics [32, p. 1337]. It is entirely possible that entrepreneurial activity, as fostered by social movements, can catalyze the creation of brand-new organizational forms [32]. Our data in this study may hint at this reverse dynamic as program directors relay the role of student voice and demand on entrepreneurial action and structures on campus. Our future work on student-level entrepreneurial activity will take up this question, responding to early calls for institutional theory to more fully account for origins of institutionalization [33].

In all, therefore, Tolbert et al.'s [32] application of institutional theory to understandings of entrepreneurship does not serve as the basis for hypotheses in this study; our study was not intended to test hypotheses (nor to result in a new theoretical framework, as discussed below). However, the propositions of Tolbert et al.'s work act as critical reference points in thinking about *why* entrepreneurship programs for engineers are what they are, *what* they might reflect, what might affect or change *them*, and what our data do and do not speak to in this regard.

3. Methods

3.1 Sample

The sample for this study draws from Shartrand et al.'s [8] longer list of U.S. entrepreneurship programs available to undergraduate engineers as of 2008 (specifics of which were made available to the co-authors upon request). By 2013, a small number of Shartrand et al.'s original 47 programs had ceased to operate or evolved into another type of program, netting 41 programs from which to select our participants. Our selection criteria prioritized (1) programs administered within or in partnership with schools of engineering, in order to be able to more deeply probe engineering-specific contexts, and (2) programs that had identifiable program directors or contacts. Applying these selection criteria and staying within the desired one-year timeline of the study (2013–14), 22 of the 41 programs were initially invited to participate in "a study of entrepreneurship program models," via emails and follow-up phone calls. Directors at 18 of the 22

programs responded ''yes,'' resulting in a response rate of 82 percent.

Directors and supporting staff at all 18 programs (distributed across 17 institutions) then provided quantitative program data about student and faculty demographics, with results summarized above and in Gilmartin, Shartrand, Chen, Estrada, and Sheppard [31]. Directors at a 12-program subset provided both quantitative data and in-depth qualitative data captured in one-on-one interviews. These 12 entrepreneurship programs at 12 U.S. institutions, respectively, compose the study sample.

Whether a program director participated in an interview or not was largely dependent on the stage of the study: following a pilot of a quantitative-based survey known as the Delivering Access to Thinking Entrepreneurially Survey (DATES) and the interview protocol at four programs, successive waves administered first the survey only, and then a merged survey and interview protocol for more comprehensive data collection using a single instrument. There were little to no differences between the larger group of 18 and the 12-program subset in terms of program characteristics and characteristics of the institutions in which the programs were housed, nor were there substantive differences between the pilot and non-pilot interview data.

Table 1 presents details on the 12 programs in our sample. Most programs have been in existence for at

Table 1. Characteristics of entrepreneurship programs in interview sample

	Administrative home of program	Credential type	Regional location of institution in U.S. (Carnegie 2012 data)	Institutional classification (Carnegie 2012 data)	Public vs. private institution (Carnegie 2012 data)	Number of engineering bachelor's degrees awarded in engineering school (ASEE 2011 data) (ranges)	Total number of engineering undergraduates enrolled in program in a given year (Data collected for research project)	Total number of non-engineering undergraduates enrolled in program in a given year (Data collected for research project)
Program 1	Outside of engineering	Certificate/ Fellowship/ Concentration	West	Research university	Public	501–1000	5	60
Program 2	Within engineering	Certificate/ Fellowship/ Concentration	Midwest	Research university	Public	1001–1500	363	190
Program 3	Within engineering	Minor	East	Research university	Public	501–1000	25	73
Program 4	Within engineering	Certificate/ Fellowship/ Concentration	Midwest	Research university	Public	1001–1500	64	266
Program 5	Within engineering	Certificate/ Fellowship/ Concentration	South	Research university	Public	0–500	110	0
Program 6	Within engineering	Minor	East	Research university	Public	1001–1500	156	104
Program 7	Within engineering	Minor	East	Research university	Private	0–500	73	5
Program 8	Within engineering	Certificate/ Fellowship/ Concentration	West	Research university	Private	0–500	10	2
Program 9	Within engineering	Minor	East	Research university	Private	0–500	119	217
Program 10	Cross-disciplinary, inclusive of engineering	Major	East	Research university	Private	0–500	Not applicable (major)	Not applicable (major)
Program 11	Within engineering	Minor	East	Master's college/ university	Private	0–500	43	0
Program 12	Within engineering	Minor	Midwest	Special focus institution: School of engineering	Private	0–500	Enrollment data not collected	Enrollment data not collected

ASEE 2011 data are from ASEE Profiles of Engineering and Engineering Technology Colleges. Carnegie 2012 data are from Carnegie Classifications Data File.

least ten years. Thus, these are established programs with several years of experience to draw from in explaining growth and operations. Notably, two programs were planning for administrative transition at the time of our study, from an administrative model based in engineering to a cross-disciplinary, campus-wide model. Both programs are classified as ''within engineering'' for reporting.

We analyzed how the institutions at which the 12 are located compared with the larger universe of U.S. institutions housing engineering schools. Institutions in the western and southeastern parts of the U.S. are underrepresented, and institutions in the east are overrepresented, as are research universities. Sampled institutions tend to have large engineering schools and a higher proportion of women engineers as compared with population medians. This limits the generalizability of the sample to the universe of U.S. engineering schools based on institutional characteristics alone, although with our exploratory qualitative research, wide-scale generalizability was not the primary objective of sampling. Rather, this work looks for patterns, themes, and ideas across a varied sample, in our case in search of characteristics and components that define models of formal entrepreneurship learning. Additional discussion of study limitations is provided at the end of the manuscript.

3.2 Instrumentation

As noted, the data for this study primarily draw from one-on-one interviews with program directors. Designed to address our research questions, the semi-structured interview protocol covered four major areas shown in Table 2. The protocol was built over a multi-month period by a larger research team. We developed interview questions to serve as a complement to previous work [namely, 4, 8, 9, 28] as opposed to basing a protocol around a specific theoretical framework. We also drew on findings from SageFox Consulting [17]. SageFox conducted a survey of ASEE individual members in Fall 2012 to identify faculty and administrator attitudes towards entrepreneurship. ''Creativity'' and ''opportunity recognition'' were identified as top components of entrepreneurship by survey respondents, and we integrated these concepts into our protocol, especially around questions of pedagogy, accordingly. Two senior research advisors who acted as independent reviewers of our project provided critique and recommendations for protocol design, based on their extensive research in entrepreneurship education for engineers.

The interview protocol was piloted in February/March 2013 with four programs. The final version of the interview protocol, used in the remaining eight interviews throughout July and August 2013, was modified such that several questions about student and faculty demographics were added (these were initially asked in the accompanying DATES questionnaire), and a small number of questions that had not yielded sufficient information in the pilot were dropped. Among the latter were questions about the role of industry in the program, the program's approach to teaching ''value creation'', and the program's connection to engineering design, leadership, and innovation communities. The complete and final interview protocol is available upon request.

Interviews generally required 60 minutes. All were conducted by phone. The pilot interviews were conducted by multiple research team members (one interviewer per conversation); the remaining interviews were conducted by the lead researcher. Interviews were taped with participants' permission. Participants were assured of confidentiality

Table 2. Interview protocol design

Research Question (RQ)	Interview Protocol Domain	Sample Interview Questions
1,2	Program history and framework	*In which year did undergraduate students first enroll in this program? Why did the program get started?*
1,2	Characteristics of undergraduate student participants and program learning goals	*What are the goals of this program in terms of undergraduate learning and development?*
1,3	Program relationships with broader on- and off-campus communities	*How does this program differentiate itself from other entrepreneurship programs and activities on campus?*
3	Program pedagogical approaches	*How would you describe this program's approach to 'creativity' if you were explaining this to a school that was looking for more information about pedagogies and strategies?*

Note: **RQ1**: How do formal entrepreneurship education programs for undergraduate engineers get started (especially within schools of engineering), and how do they grow? Which contextual characteristics appear to influence growth? **RQ2**: What are the educational missions of such programs? How do these programs define ''entrepreneurship'' and related concepts? **RQ3**: What are the pedagogical features of such programs, and how are these similar to or different from other types of engineering pedagogies? **RQ4** and **RQ5** (see Section 1) are addressed by analysis of responses to all four interview domains.

and presented with a Research Information Sheet as well as a copy of the protocol before the conversation. In some cases, conversations did not cover all questions on the protocol due to time constraints; in these instances, follow-up questions, mainly related to student and faculty demographics, were posed via email.

3.3 Analysis methods

Although much qualitative research takes a grounded theory approach, our study was not expressly designed to develop new or expanded theories about entrepreneurship education or entrepreneurial behavior. As Corbin and Strauss write, "grounded theory seeks not only to uncover relevant conditions but also to determine how the actors under investigation actively respond to those conditions, and to the consequences of their actions" [34, p. 419]. We are not necessarily aiming to draw links between condition, response, and consequence. However, the data in this study do add to a contextual understanding of entrepreneurship opportunities for engineers that can help to set the stage for theories of entrepreneurial behavior among students, and theories of school-level behavior and structures surrounding entrepreneurship (see earlier references to Tolbert et al. [32]). Moreover, estimates about actions and outcomes might be reasonably postulated on the basis of our findings and tested using larger samples and/or different methods.

In addition, our study uses several analytic techniques common in qualitative research, if stopping short of a grounded theory framework. Following professional transcription of interview data, analyses proceeded in two phases. For the first phase, the research team developed and applied descriptive content codes to each interview transcript, i.e., codes that roughly corresponded to the interview questions. Examples were a code reflecting program goals for undergraduate learning and development, and a code reflecting a program's approach to teaching creativity. Four analysts established code validity using the four pilot transcripts; two of these analysts applied the coding scheme to the remaining eight transcripts. The inter-rater agreement between these two analysts was "very good," as indicated by a pooled Cohen's kappa of .94 [35–39].

At the end of this first phase, the team identified four domains of data to delve more deeply into, in line with the organizing research questions: (1) program "founding stories" and how programs have grown and/or changed over time, (2) program goals and definitions of entrepreneurship, (3) program approaches to teaching fundamental entrepreneurship components, and (4) program contexts, both on and off campus. One analyst was assigned to each domain; these analysts then developed subcodes in their respective domains to draw out ideas, themes, and patterns in each area. Techniques included clustering and counting, constant comparison, axial coding to explore relationships among codes, and checking that patterns were plausible [34, 40]. The analysts met regularly to discuss their emerging codes and make connections across codes. Domains were coded until saturation of themes was reached, i.e., new thematic categories were not appearing within domains and, as data from successive interviews were brought into the analyses, the same families of ideas and comments were coming up again and again (we did not apply the saturation concept to selecting the number of interviews to be conducted, but to the coding process and the diminishing returns to continuing a search for unique themes, heeding Bowen's point that "claims of saturation should be supported by an explanation of how saturation was achieved and substantiated by clear evidence of its occurrence" [41, p. 137]). Inter-rater agreement tests for select coding sets were conducted; the pooled Cohen's kappa ranged from .79 to 1.00. Data were securely stored and analyzed in the cloud-based Dedoose platform.

The final dataset for this study included 34 umbrella codes and upwards of 150 sub-, or "child," codes. Narratives surrounding these codes are presented in the Findings section, with the Discussion intended to show how the parts sum to inferences about program models and implications for entrepreneurship education for engineers. We verified trustworthiness of our methods and findings by sharing earlier versions of our manuscript with (1) a study participant and (2) an individual who is directly involved with entrepreneurship program development on a large scale in U.S. higher education but who was not involved in our study. Both persons provided valuable feedback and checks on our statements, e.g., affirming the validity of our conditions of program creation and the range in definitions of entrepreneurship, and encouraging us to clarify the applicability of our findings to new program development. Their input is reflected in the current manuscript.

4. Findings

We organize our findings such that we begin with an analysis of program creation and growth, and then turn to program missions and definitions of entrepreneurship (in this analysis, program "goals and frameworks" are conceived as reflective of "missions"). We then share findings about program pedagogies. We weave contextual aspects of these

programs—departmental, institutional, regional—throughout this section.

4.1 Program creation, growth, and growth challenges

4.1.1 Program creation

In our sample, two types of conditions predated entrepreneurship program creation: intent-based conditions and process-based conditions (see Fig. 1). Intent-based conditions speak to *why* a program was created, whereas process-based conditions reflect *how* a program came to be. All conditions were not required to start a program, but directors at every program in our sample referred to at least one, whether intent- or process-based.

Beginning with intent-based conditions, many programs were created to help engineering students develop specific skills that they may not have had the opportunity to develop elsewhere in the engineering curriculum. This dynamic had two components: a desire to impart business skills to engineering students, and a perceived need to correct for deficits related to entrepreneurship learning for engineers. Speaking to the former, one program director stated that program founders had recognized that engineers needed more familiarity with business practices to "get [their ideas for products] to market." Another director stressed that engineering students needed to have "the business-speak and terminology insight to be able to have a good conversation [with non-engineers]." And still another believed that having business acumen would give engineering students an advantage over their peers who hadn't taken business-focused classes:

> [Students] need to have some idea of what business is about if they are going to successfully compete against their peers from other schools.

Programs also were started with the intent to address campus deficits related to entrepreneurship education per se. Directors at six of the 12 programs acknowledged there had been a barrier in learning about entrepreneurship before creating the program—this was because the institution did not have a business school (a traditional purveyor of entrepreneurship content), did not have an entrepreneurship program on campus, or had course enrollment practices that discouraged engineers from taking business-based entrepreneurship classes. One program director discussed how, before founding his program, "[Engineering students] . . . had very few ways to learn about [entrepreneurship]. . . That meant that they had to go try and fight their way into a business school class, which was pretty tough."

Whatever the intention for program creation, programs also needed a way to make this intent a reality. Programs did so with dedicated leadership, critical "doers" (people who design and implement the program), and/or catalytic funding. These conditions echo the findings of Standish-Kuon and Rice [28], who noted the importance of having "champions," i.e., individuals or small groups committed to creating an entrepreneurship program. Three programs in our sample were created as an initiative or vision of a top-level administrator at the university, as reflected in this quotation:

> We started the [entrepreneurship center in which our program is housed] because it was part of our dean's initiative to address the changing face of engineers in today's global economy.

In parallel with leadership, critical doers were generally a small group of people or one person who created the curriculum, structured the program, and/or conducted the behind-the-scenes work for the program. In our sample, leaders often hand-

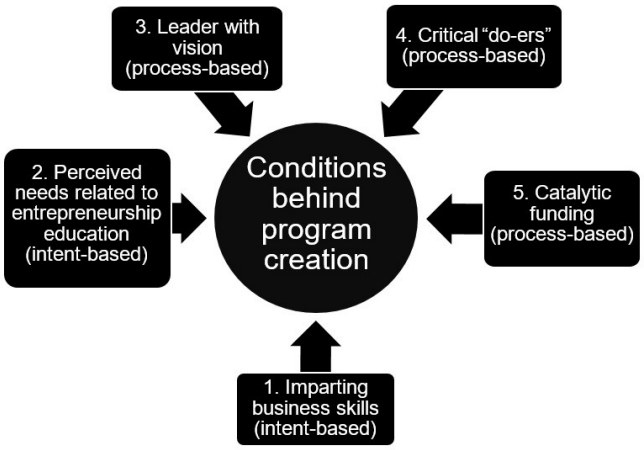

Fig. 1. Intent- and process-based conditions driving entrepreneurship program creation for engineering students.

selected doers to start the program, sometimes recruiting them from industry. According to program directors, industry experience was coveted because it provided insight about what is relevant for aspiring entrepreneurs.

Catalytic funding was the last process-based condition for program creation. Four program directors reported that endowments catalyzed the creation of their programs; another program was built on a targeted grant from a private foundation dedicated to entrepreneurship education. Two programs initially were funded through seed money from the college of engineering. One of those programs now uses tuition from the students in their classes, which incentivizes professors to "keep their courses fresh" so the program "can continue to grow."

4.1.2 Program growth

Our study instrumentation did not request student participation numbers at the time of program creation. However, five directors shared both baseline and current numbers of participants. Four of these respective programs saw large increases in student participants over time, with the remaining program capping student enrollment at a fixed number each year. Other directors reported enrollment increases, although did not specify by how much.

Previous research points to important factors for scalability of an innovation or program in education, which include students' engagement, students' perceived self-efficacy, and faculty preparation (i.e., teacher's knowledge on a subject) [42]. Our results are in line with these factors. For example, among the programs for which we could calculate percentage growth, directors attributed their program expansion to student input and motivation. One director noted that increasing enrollments reflected the program's "relevance for students in terms of . . . their career aspirations"; students wanted "something that could expose [them] to problem-solving and set the context for things that happen in the business environment." Programs also grew because students talked highly of the entrepreneurship-focused classes:

> [One of the top factors in growing this program has been] largely word-of-mouth [among students]. . .[our core] course was so different, [and] they had never had a course in engineering that really got into the entrepreneurial, the business side of it.

Industry was a resource for program growth, in terms of supplying experienced instructors for courses and mentors for students. One program director attributed his program's popularity with students to the presence of faculty who had real-world expertise:

> The faculty whom we have teaching it all have real-world business start-up experience, so it's not just academia, it's people coming from the business world who have actually done start-ups. I think [as a result] we've developed a pretty good rapport with the undergraduate population.

Another director stated that his program had "a fair number of businessmen who are encouraging students to start businesses [and] helping mentor them." This comment raises the question, however, of whether industry resources compound the gender imbalance among participating engineering students and faculty [31].

Curricular contexts in the business school also have a hand in program growth. At one university, after the business school restricted the opportunity for engineers to minor in business, the number of participants in the engineering entrepreneurship program increased:

> The business school used to allow [engineering] students to take classes in the academic year, and then they could get a business minor. . .Now they offer a summer business institute where you can get the minor. . .I think that's discouraged students from [enrolling]. . .[As a result, the engineering entrepreneurship program] has become very popular.

4.1.3 Challenges to program growth

Program directors discussed "growing pains" or issues that inhibited program growth; some of these were resolved and others were ongoing. For instance, programs did not always have adequate faculty resources to develop their curricula. One director said his "biggest struggle" was "[getting] tenure line faculty from across the departments of engineering to . . . dedicate a full semester of teaching a course that's outside of their normal teaching realm." Another program had to discontinue an "innovation and creativity" course after the original faculty member left, since program leaders had "never found somebody [else] who could [teach] it." To address this challenge, leaders decided to infuse innovation and creativity components into existing classes.

Sometimes finding the right person to fill a position was critical to overcoming program challenges. For example, the dean of one engineering school brought in a tenured faculty member to facilitate the process of approving new courses: "[In order to get new courses through the curriculum committee, the dean] decided he wanted . . . a tenured faculty member [to help lead the program], so that some of those issues . . . of being able to muster these things through the various committees would go away."

4.1.4 Future changes

Standish-Kuon and Rice [28] noted that as pro-

grams pursue entrepreneurship education initiatives, they often evolve from their original form, changing in leadership and/or administrative arrangements. Two of the programs in our sample were shifting from being housed in the engineering school to being a campus-wide program in the upcoming year. At one of these two programs, the director noted that having the program's core classes run by a central administrative unit provided an opportunity to "push our . . . students to go much farther than we've had an ability to do thus far." This program was evolving to provide engineering students with a more focused engineering entrepreneurship experience, even in a multidisciplinary context: "[We plan on] having a specific practicum that will only address engineering-focused projects, as opposed to having [business-focused ventures] in there with [an engineering-focused venture]."

This shift raises the issue of how much cross-disciplinary interaction benefits engineering students' entrepreneurship learning. Approaches varied among the programs under study. At another program run by the school of engineering, for instance, the affiliated student entrepreneurship center was located physically at the business school. The program director asserted that this location was "strategic" because they "wanted to engage [their] MBA students along with [their] engineering students" in an informal, non-curriculum-based way. The formal engineering entrepreneurship program and its courses remained separate from other entrepreneurship programs on campus, and there were no near-term plans to alter this structure.

4.2 Program goals and frameworks

4.2.1 What are entrepreneurship programs designed to accomplish?

Directors described a range of program goals for undergraduates, and not surprisingly, "starting a business" was among them. Some programs emphasized new venture creation as a key outcome:

> Our [expectation] is that we would see some level of venture creation come out of [program participation] while [students] are still undergrads . . . [Students] learn more by doing. We would rather them try and start it than to just do case studies and kind of leave it at that.

Not every program articulated this specific goal. In fact, two of the twelve programs studied took the opposite stance, as this program director indicates:

> [In one of our courses] we develop a business plan and we do pitch it to a panel of venture capitalists, but it's purely for the course . . . we're not into developing new products or actually working on that . . . We think, statistically, at this point in a student's career, it's premature to be talking about starting a company.

Teaching engineering students "business fundamentals" was a more commonly cited goal, which suggests that entrepreneurship programs can serve as vehicles for business education in settings where little business content traditionally exists. This goal is consistent with intentions behind program creation that were discussed earlier, i.e., to provide engineering students with opportunities to develop business skills. Relatedly, at least five program directors emphasized that they were preparing students for jobs within traditional organizations (potentially offering "intrapreneurship" opportunities) as much as start-up environments. However, where many engineering entrepreneurship programs tended to depart from "standard" business school offerings was the emphasis on technology ventures and technology commercialization processes, bringing them in line with Byers, Dorf, and Nelson's [43] definition of "technology entrepreneurship." This director's comment highlights the technology focus:

> Our interest is in scalable, technology-based businesses . . . that's been the focus since the beginning, and engineering was a logical place to go and do that . . .We welcome any technology from across campus now into the [partner] incubator, but we don't focus on non-scalable, family, lifestyle type businesses.

A small number of "specialized" programs zeroed in on one skill set in particular. For instance, one program director conceived of entrepreneurship education as a "Trojan horse" for supporting the development of leadership ability in entrepreneurial contexts:

> This [program] is on the border between being an entrepreneurship work-study program and a leadership work-study program . . . This is about learning about leadership lessons . . . and specifically what it means to be a leader or manager in one of these high-potential enterprises.

Another program focused exclusively on helping engineering students develop an "entrepreneurial mindset." Two additional directors cited "entrepreneurial mindset" as a core (although not sole) goal. Interestingly, an "entrepreneurial mindset" had different meanings at these three programs. For instance, one program director discussed mindset in terms of developing the propensity to "constantly look for opportunities." For another program director, mindset was about "taking ownership of your future" and being able to "work with limited resources" and "corral yourself and motivate people around you to meet an end goal."

4.2.2 Social entrepreneurship

The interview protocol did not include specific questions about "social entrepreneurship," which can be defined as entrepreneurial action that directly

addresses and tries to ameliorate social injustices with a "social value proposition" [44]. Nonetheless, this issue did emerge in several conversations. At least four programs integrated social entrepreneurship into their organizing framework, for varying reasons: to incentivize enrollment; to attract more diverse students, including women and students from underrepresented racial/ethnic backgrounds; and because conceptually, argued one director, for- and non-profit entrepreneurship have the same end-goal—to make change.

Yet just as many interviewees saw their programs as solely focused on more commercial forms of entrepreneurship. For example, one director noted that other units on campus were devoted to social entrepreneurship across all disciplines, which allowed this program to specialize and distinguish itself as commercial venture driven within engineering. As with many aspects of the entrepreneurship programming opportunities under study, this decision was clearly situated within the larger institutional ecosystem. Programs at public *and* private institutions, moreover, included (or excluded) social entrepreneurship in their frameworks, indicating that overall institutional mandates and missions may be less influential on the ways in which entrepreneurship learning environments are structured than are the particulars of individual institutional environments and histories.

4.2.3 Evaluating progress towards goals

Programs did not always measure progress towards their goals. When asked about their current evaluation practices, program directors described a set of metrics that included enrollment numbers, course evaluations and, less frequently, retention rates and grades. Some program evaluations employed interviews with alumni to gain insight into program impact; only one director mentioned the use of pre/post surveys to study student change. Four directors asserted that new business creation was not something they counted—even when it was a desired or expected student outcome. Similarly, programs did not evaluate the progress or success of their program based on gains in student knowledge of, for example, technology commercialization (unless grades were perceived as proxies for such). Rather, output metrics that focused on participation—enrollments, degrees—were more prevalent.

One program director tried to make connections between program participation and later behaviors, such as applications to "our new venture competition, or for one of our innovation prizes." Other directors emphasized the difficulty in "tracking" students to make such links between learning and behaviors over time. Together, these data point to a potential disconnect between what programs aim to equip students with and what constitutes evidence of program success.

4.3 Definitions of entrepreneurship

Faculty or university-level consensus on the definition of entrepreneurship might be thought of as part of a program's organizing framework. However, our data indicate that participants within a program, much less across programs, do not always have an agreed-upon definition. One program director explained that "we're struggling with what the definition of 'entrepreneur' is." Another director agreed, stating "[many] people would say [making a difference] is an underpinning of entrepreneurship here . . . [but] the school of engineering [component of our program] would say . . . 'high-growth potential,' 'value created out of innovations'—that would be their definition of entrepreneurship."

A subset of interviewees indicated that their program definition was less contested, possibly because it was broad and process-based. One director stressed creative aspects of entrepreneurship, particularly in the context of limited resources:

> I've always used the Harvard definition that entrepreneurship is the ability to approach problems and opportunities without regard to resources currently on hand . . . And that's kind of a broad definition . . . It means that you want to accomplish a task that you see or think needs to be accomplished, and you want to be able to do it without worrying about having to first have somebody give you the budget and the line items to make it happen.[1]

At this program, such a definition went hand-in-hand with an emphasis on both technology and social entrepreneurship, and an emphasis on being entrepreneurial within existing organizations as much as starting new ones. The framework of this program speaks to an inclusive model that accommodates entrepreneurship in many forms. This program was not alone in such inclusivity—most other programs in our sample had multiple goals and definitions in their programmatic rubrics.

Other interviewees approached entrepreneurship as a mindset (itself variably defined) rather than a specific set of behaviors, though at the same time underscoring its marketplace applications:

> [Our program goal is] to create entrepreneurially minded engineers . . . So, the idea is for them to understand the theory and practice of engineering, but also to understand there's a business aspect to it, and that you need to be able to make money out of a product that's developed.

As with the previous example, this program was not alone in promoting a "business sense," which

[1] For this particular "Harvard definition," see Howard Stevenson's work, e.g., Stevenson [45].

implies a kind of abstract awareness of commercial aspects of product development, while also encouraging practical knowledge of how to create products that are marketable and profitable. "Entrepreneurship" encompassed many ideas and behaviors in these curricular environments.

4.4 Pedagogical aspects and features

A variety of pedagogical approaches characterized the programs in our dataset. Most of these pedagogies were not unique to entrepreneurship education; they are well-researched teaching techniques that are known to support and encourage student engagement through experiential learning. For example, this director explained, "I think entrepreneurship education should be 80–20. When I say 80–20, that means 20 percent absolutely are fundamental skills that you have to learn . . . but 80 percent of it is you have to put these into action and see what happens. Without that action-by-doing, I don't think we're . . . teaching entrepreneurship . . . Until they take ownership for the execution and delivery of what it is they're trying to do, the learning is significantly different."

The impact of this active learning approach was seen in the culture of the classroom environment and the "ambiguity in the environment and putting minimal limitations on the students. . .to create their own project and explore what it feels like to not have strict guidelines like they're used to in a lot of their classes." This sense of disharmony and feeling "out of [one's] comfort zone" and "[making students] do something they haven't done so before" resulted in creative solutions:

> It creates a very high level of [discomfort] . . . initially, and then, once [students] fail a couple of times, then they realize, oh, it's okay to fail, I just need to try something different and keep going. So, we try to build failure into this process . . . and it seems to be a very effective method of getting them to try new and different ways of doing things.

From an operational perspective, these programs often relied on the experience of their faculty members, many of whom were recruited for their real world entrepreneurial expertise. Faculty knowledge was further leveraged through team teaching of courses. The student response to this approach was often positive due to the "relevance that this brings into the classroom, the anecdotal battle stories from the trenches, the sidebars, the color that can be added in a class."

Interestingly, program directors talked about integrating their curricula with larger educational goals in one of two ways: (1) by aligning entrepreneurship with engineering contexts and skills that undergraduate engineers are already learning, or (2) by positioning the program as a complementary part of a larger liberal arts education. As an example of the former, this director noted:

> We try to focus on . . . what can engineering students identify with from their disciplinary perspective, and then think about how that rolls into project management, how that rolls into product development or manufacturing or customer identification. So, really trying to project entrepreneurial principles onto a backdrop of engineering discipline and technology that the students typically will already have.

However, to the latter, a director of another program housed in engineering stated, "The program is reinforcing what [students have] learned, hopefully, in the humanities courses, the social science courses, as it relates to this wonderfully attractive notion of entrepreneurship."

5. Discussion and implications

Drawing from a sample of 12 entrepreneurship programs offered to undergraduate engineering students and using qualitative methods of analysis, this study was designed to illustrate the "nuts and bolts" of formalized (program-based) entrepreneurship learning opportunities for engineers, and help to define and map models of these learning opportunities from creation to operation. Our research questions were grounded in previous research on entrepreneurship programs in the U.S., namely Besterfield-Sacre et al. [9], Duval-Couetil et al. [4], Shartrand et al. [8], and Standish-Kuon and Rice [28].

5.1 Commonalities across entrepreneurship programs

Our first three research questions focused on program *creation and growth*, *missions and definitions*, and *pedagogical features*. In addressing these questions, our findings point to several commonalities across programs. Entrepreneurship programs for engineers center on educating students about business principles, often in the context of technology commercialization processes and pathways. These programs tend to be started in response to a perceived need for entrepreneurship and/or business education for engineering students, filling a gap in current offerings for engineers not yet addressed by other schools or units on campus. Funding is, unsurprisingly, key to program development, whether in the form of seed, grant, or endowment monies. Students play a key role in program growth; specifically, student demand for courses that can prepare them for business environments drives growth just as "spreading the word" among their peers does. Faculty resources can pose a challenge, as limited numbers of faculty are available to teach some courses and/or "champion" these courses with

curriculum review committees. Experiential, hands-on learning activities mark these programs, reflecting a belief that students learn entrepreneurship (however defined) by doing it.

5.2 Variation across programs and the absence of a single model

Our fourth research question focused on identifying a *model, or models, of formal entrepreneurship learning opportunities for undergraduate engineers*. Those program commonalities described above hint at a single model. However, the variation across programs underscores adaptability of programs to local contexts, and the conditionality of student outcomes based on program bent. For instance, findings suggest that some programs actively emphasize student start-ups, others actively deemphasize student start-ups, and the balance leaves the issue of student start-ups not fully articulated (there could be many reasons for this "light treatment," including close collaboration with partner incubators, centers, or student entrepreneurship clubs that can provide start-up support more aggressively). The skills that programs focus on vary in specificity as well—most programs tend to promote multiple competencies, skills, and applications, while fewer might be characterized as "niche programs" that are organized around one core competency such as "mindset" or "leadership."

Variation also emerged with respect to how much engineering students interacted with students from other disciplines. One viewpoint was that engineers should have a focused technical-entrepreneurship experience by way of an elective track exclusively designed for them, and interact with non-engineering students in "core" or common program courses. Another viewpoint was that a program would exclude non-engineers from enrollment, but encourage more informal interactions with business students in particular at campus entrepreneurship centers. Still other programs mixed engineering and non-engineering students together for all courses, raising questions about differences in students' entrepreneurship motivations by field and how curricula are designed to accommodate these differences [46]. Data in Table 1 provide further evidence that not all programs are the same—enrollments can range widely, as can the type of credential offered.

These findings together show that entrepreneurship programs for engineers are situated and specific, with different goals, skills, and learning environments at play. There is not, in other words, a single all-encompassing program model. Keeping Tolbert et al. [32] in mind, the precise set of beliefs and actions that drive these programs into being are not fully known in our study. But we are able to infer, through directors' comments, a set of institution-level conditions that predate program creation, and we heard from directors about the significance of student voice in helping these programs grow.

5.3 Implications for assessment, new programs, research, and engineering education

Our fifth and final research question looked at the implications of our results for four major areas of interest to entrepreneurship researchers and educators: *assessment of student outcomes*, *new program development*, *educational research*, and the *future of engineering education as a whole*.

Beginning with *assessment*, our findings suggest that student outcomes can vary not only across programs, but even within a single program that has multiple objectives and definitions. In other words, not all students may graduate from the same program with the same set of skills, plans, or experiences. Such variability presents a potential challenge to evaluators and researchers who study student outcomes in entrepreneurship learning environments on a large scale. A single measure of program participation across a multi-site sample may not have a strong association with, for example, "intent to start a business." Rather, one must ideally bring details about students' learning experiences, such as the content covered in courses, the definitions employed by faculty, and the types of co- and extra-curricular activities that accompany program participation, into view and analysis.

Moreover, single case program assessments may not always be comparable across sites—what one program assesses (e.g., venture creation) could be different from what another assesses (e.g., changes in entrepreneurial mindset). This variation in itself is not problematic; potentially more so is our finding that assessment organized around specific goals for student learning or behavior generally does not occur, i.e., outcomes are measured narrowly, if measured at all. Thinking about the larger educational systems within which these programs exist, accreditation processes could provide tangible ways to assess multiple learning outcomes of these programs that are relevant to professional engineering practice [47].

Implications of these findings for *new program development* are numerous. Fig. 2 summarizes questions for program development that are grounded in the major domains under study in research questions 1–3. Educators and practitioners might use these questions as starting points in putting together their concept plan for entrepreneurship curricula. We also see important questions relating to the role of these programs in engineering students' career trajectories. Sheppard, Antonio, Brunhaver, and Gilmartin [48] report that just under one-third of

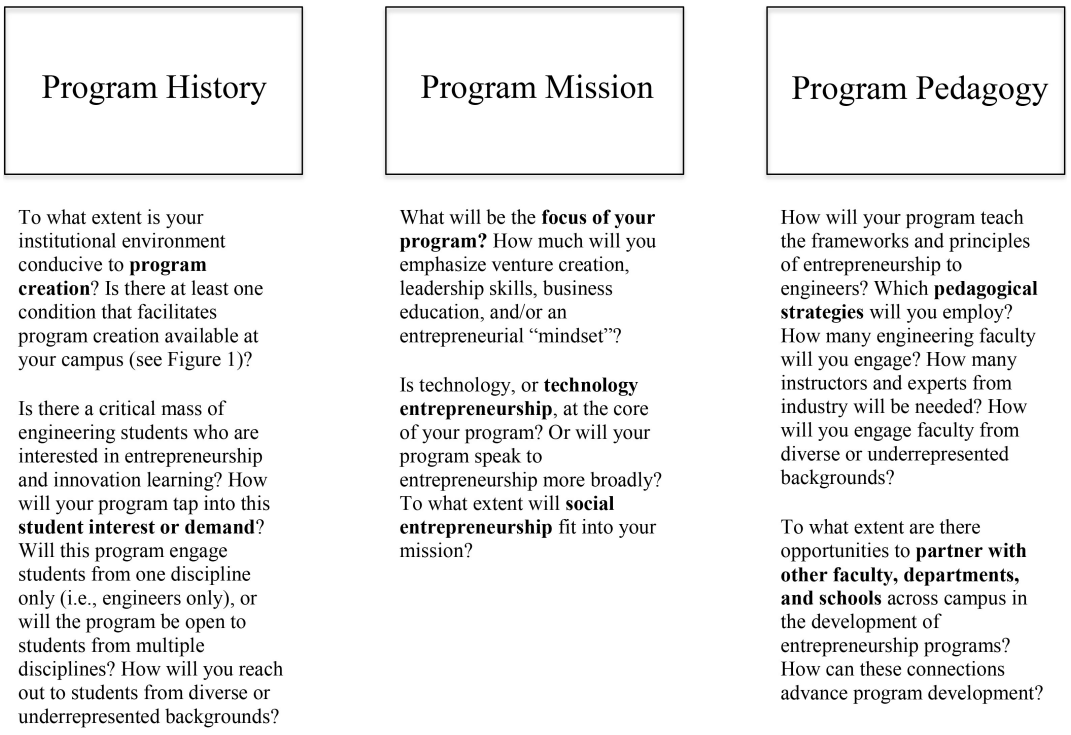

Fig. 2. Questions for educators and practitioners who are designing new entrepreneurship programs for engineers, by domain of current study.

undergraduate engineering students are focused exclusively on engineering pathways after graduation, about seven percent are focused exclusively on non-engineering pathways, and the balance is eyeing a mix of engineering and non-engineering work (and/or are uncertain). Further, about 60 percent of engineers are in engineering positions two years after graduation. Who among these students do, or should, entrepreneurship programs reach? Are programs disproportionately attracting those students focused on non-engineering work? Do engineers with a strong technical orientation see these programs as relevant to what they do, or want to do? Does the vast majority of students with mixed plans see entrepreneurial pathways as real possibilities? Or does entrepreneurship systematically attract a certain type of student (see [49]) unless programs actively recruit participants across a diverse population? Considering these questions may inspire new programs to consider which perspectives are missing from their "default" environments, and how they might widen their scope.

Implications for *educational research* are similarly rich. For instance, although women engineering students may not be underrepresented in entrepreneurship programs (compared with their representation in engineering more generally), gender differences in entrepreneurial interests, intent, and self-concept remain significant [31, 46, 50]. At least one program director in our study cited social entrepreneurship learning opportunities as a means to attract more women and underrepresented racial/ethnic minority students to such a program. Future research needs to examine the entrepreneurial pathways of women and men engineers, and engineers from diverse family and ethnic backgrounds, as these intersect with varying programmatic emphases on social ventures, as well as with the presence (or absence) of diverse entrepreneurship faculty.

As another example, several program directors reiterated that the entrepreneurial skills being taught in their programs could equip students as much for a start-up environment as for a position in a larger, more traditional organization, pointing to possibilities around "intrapreneurship" [51–52]. However, to what extent is a programmatic emphasis on "intrapreneurship" aligned with the demands and parameters of first engineering jobs? More research is needed about how engineers are able to and do act "intrapreneurially" in a traditional workplace environment, in order to enrich thinking about where intrapreneurship falls in entrepreneurship and engineering learning.

One particularly consistent element across the programs we studied lends itself to implications for *engineering education as a whole*: the emphasis on business education for engineers. Despite the multiplicity of possible outcomes described above, it seems reasonable to predict that engineering

students who have participated in entrepreneurship programs would have, on average, greater business literacy than do engineering students who have not participated in such programs. To this supposition, we pose the following question: Is the goal of developing engineering graduates who are more business-minded aligned with other agendas and belief systems in engineering education (and higher education more generally)?

We pose this question more as a call for programs themselves to reflect on where they fit in larger conversations about the future of engineering and higher education. Relevant "currents" include:

- University interests in producing competitive engineering graduates who can meet the demands of a global economy [5].
- Local and federal policymakers' desires to increase the supply of entrepreneurs [53].
- The engineering community calls for students to become problem-framers, not just problem-solvers [7].
- The popular debate in U.S. education on the professionalization of the undergraduate experience and the future of the liberal arts [54].

By drawing connections between these four currents and program frameworks, entrepreneurship programs would be arguably better positioned to capitalize on and institutionalize the unique aspects they bring to engineering education, and/or work synergistically with other units on campus to deliver rich learning experiences for their students.

6. Limitations

Two key limitations to this study are the absence of student perspectives and the narrow focus on formal programming. We heard from program directors about the importance of student demand, and can make some extrapolation to the possibility of student-led social movements and/or entrepreneurial activity effectuating change. But we do not have the student voice on program goals, pedagogy, or impact, or their reasons for participating in entrepreneurship activities to begin with. Taks et al. [26], who focus on how engineering students perceive the value of entrepreneurship studies, represents a good place to start to develop these insights.

Moreover, multiple, more informal (less curriculum-based) ways of learning about entrepreneurship exist, as the University Innovation Fellows program [55] attests, and experimentation is even happening in core engineering courses such as statics [56]. The current study probes only one dimension of the innovation and entrepreneurship ecosystem, which expands beyond formal curricular and informal extracurricular activities to also include companies, alumni, and culture on and off campus. The next step is to consider more deeply the interlocking components of these ecosystems, how ecosystems come to be, and how they contribute to engineering students' learning, pathways, and choices in a longer-term sense. This next step would involve a larger sampling frame, several units of analysis, and longitudinal data. Close case-study research designed to build theory [57] also would help to address these questions, from a different angle.

7. Conclusion

This study explored the many aspects of entrepreneurship programs for undergraduate engineering students, in light of increasing demand for students to have entrepreneurial awareness and entrepreneurship-related skills, but uncertainty about program goals and structures. Our research questions centered on: program histories, missions, and pedagogies; identifying a model, or models, of entrepreneurship learning for engineers; and implications for research and practice. Our findings underscore program commonalities, but perhaps even more so, program variation and local adaptability. These findings can set the stage for empirically-driven hypotheses about engineering student outcomes as a function of different types of learning environments and program emphases. For instance, it is possible to envision that programs with strong messaging and content around commercial start-ups would not only attract a different type of student than would a program that takes a more wide-ranging approach to goals and definitions, but have a net positive effect on the likelihood of venture creation. Testing these types of hypotheses, and building theory around entrepreneurship learning using these and other methods, would push this line of inquiry even farther.

Engineering education stands to gain from a broader view on what students can and should learn, in terms of supporting engineers in their ability to contribute to and lead major innovations of the next decades. There is a great amount of discussion in engineering education about the specifics of this broader view—what exactly does this mean, and how can this be integrated with learning the "fundamentals" of engineering? The programs in our study show the complexities, opportunities, and flexibility in designing one part of this broader approach, formal entrepreneurship education for engineers, which then lays the groundwork for the next major generation of programming possibilities. Situating such possibilities in the context of other major conversations in engineering education

and students' own evolving career goals will be critical to scaling entrepreneurship learning in engineering environments.

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