



Exploring what we don't know about entrepreneurship education for engineers

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Ms. Laurie Moore, National Center for Engineering Pathways to Innovation (Epicenter)

Laurie Moore is the communications manager for the NSF-funded Epicenter and leads the center's community outreach efforts. She manages the website and its content, social media accounts, media relations, email campaigns, and tells the stories of engineering faculty and students who exemplify the innovative, entrepreneurial spirit that defines the center. Laurie has worked for eight years as a writer and editor for web and print, with experience in website management and graphic design. Before joining Epicenter, she worked for the University of Southern California as the web editor for the USC Dornsife College.

Mr. Emanuel Costache, SageFox Consulting Group

Since joining SageFox in 2009, Emanuel has worked on the evaluation team for a variety of NIH- and NSF-funded projects, including the National Center for Engineering Pathways to Innovation (Epicenter). Emanuel also works closely with Epicenter's Fostering Innovative Generations Studies (FIGS) researchers and the Designing Education Lab at Stanford Univ. He lives in San Francisco, Calif.

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Florian is studying Environmental Planning and Ecological Engineering at the Technical University of Munich (TUM). His majors are Sustainable City Development, Renewable Energy, International Land Use Planning and Environmental Economics. He is also participant in the Entrepreneurial Qualification Program "Manage&More". This is a program of the Center for Innovation and Business Creation at the TU Munich ("UnternehmerTUM") which supports Innovation and Start-Up Projects. While at UnternehmerTUM, Florian was involved in a marketing project for a tourism startup (Social Tourist) and consulting for another startup that monitors super lightweight structures (fos4x). He joined the Designing Education Lab to learn more about entrepreneurial decision making for profit or non-profit organizations and social entrepreneurship in general.



Dr. Leticia Britos Cavagnaro, Stanford University

Leticia Britos Cavagnaro, Ph.D., is Deputy Director of the National Center for Engineering Pathways to Innovation (Epicenter), an NSF-funded initiative to foster innovation and entrepreneurship in engineering education nationwide. She is also a lecturer at the Hasso Plattner Institute of Design (d.school), where she teaches Stanford students of all disciplines how to build their creative confidence to become engines of innovation in their own lives, and as members of teams and organizations. She has a Ph.D. in Developmental Biology from Stanford's School of Medicine, and is a former member of the Research in Education & Design Lab (REDlab) at Stanford's School of Education. Having witnessed the journey of students who are transformed by their experience at the d.school, bringing design thinking to more people beyond Stanford has become a priority for Leticia, and she has worked with hundreds of teachers and students of all ages, as well as corporate and non-profit leaders in the US and abroad. In the Summer of 2013, Leticia engaged thousands of people from over 130 countries in learning design thinking and applying the methodology to innovate in their contexts, via an experiential MOOC (<http://novoed.com/designthinking>).

Find out more about Leticia's work at: <http://epicenter.stanford.edu> <http://dschool.stanford.edu/creativity-and-innovation-winter/> <http://teachingcommons.stanford.edu/teaching-talk/design-thinking-action-lab-1>

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Exploring what we don't know about entrepreneurship education for engineers

Abstract

What do we still need to learn about entrepreneurship education for engineers? Who better to answer this question than a group of engineering educators, educational researchers, practicing entrepreneurs and innovators, and engineering students? Such a group was convened in August 2014 to examine and reflect on current knowledge of students' entrepreneurial development and pathways, entrepreneurship programming models, and the efficacy of various curricular approaches. The event, known as the Epicenter Research Summit, was held at Stanford University and co-hosted by scholars at three universities; 70 attendees from 29 different institutions and organizations contributed to panel and poster sessions over two days. These sessions and the continuous dialogue, along with a series of individual and group exercises, allowed this community to identify gaps in knowledge about educational environments and pedagogies that support engineering students in becoming creative, innovative and entrepreneurial thinkers.

Findings from the interactive exercises led to the identification of three major research areas for future work: **Linking Outcomes to Reform, Understanding Student Diversity, and Examining Contexts**. Each of these areas includes a wide range of questions that could be collaboratively pursued in the coming years to direct the course of entrepreneurship and innovation education in engineering. This paper reviews such questions and makes recommendations for the next phase of both research and community building in this emergent space.

Section 1: Introduction

Technological innovation and commercialization continue to drive economic growth, and interest in understanding how to educate engineers to contribute to these activities is on the rise. Although a rich research space in engineering and entrepreneurship is taking shape, much remains unknown about the interrelation between engineering, entrepreneurship, and innovation education and how to prepare undergraduate engineers for the contemporary workforce and economy. For instance, to what extent are new engineers positioned to innovate and drive new ideas forward? What motivates them to be innovative, or to bring their ideas to market? Which educational environments and contextual factors support them in their next steps? Which hold them back?

In considering these questions, the National Center for Engineering Pathways to Innovation (Epicenter) convened a Research Summit in August 2014 in order to identify the "state of play" in research on entrepreneurship and innovation education for engineers. Attendees representing a broad range of positions, interests, and sectors came together to reflect on current knowledge of students' entrepreneurial development and pathways, entrepreneurship programming models, and the efficacy of various curricular approaches. The event was held at Stanford University and co-hosted by scholars at three universities; 70 attendees from 29 different institutions and organizations contributed to panel and poster sessions over two days. These sessions and the continuous dialogue, along with a series of individual and group exercises, allowed this community to identify gaps in knowledge about educational

environments and pedagogies that support engineering students in becoming creative, innovative and entrepreneurial thinkers.

This paper begins with an introduction to the research initiative at Epicenter, and then describes the Summit event, from design to results. Findings from an in-depth, qualitative analysis of data from one particular Summit exercise are presented as a way to bring “gaps in knowledge” to the fore. These data were coded and categorized into themes that fell into one of three major research areas: **Linking Outcomes to Reform, Understanding Student Diversity, and Examining Contexts**. The paper concludes with a discussion of how research in these three areas might proceed, and makes a recommendation for a white paper series to document what is known and what needs to be known about entrepreneurship and innovation in engineering education.

Section 2: The Roles of Research in Epicenter

Epicenter is an initiative funded by the National Science Foundation (NSF). It is directed by Stanford University and VentureWell (formerly NCIIA), a national non-profit organization that promotes innovation and entrepreneurship education. Epicenter was established in 2011 to catalyze the infusion of innovation and entrepreneurship (I&E) into undergraduate engineering education.¹ Epicenter’s mission is to develop programs and initiatives that empower U.S. undergraduate engineering students to bring their ideas to life for the benefit of our economy and society. To do this, Epicenter helps undergraduate engineers connect their technical skills with the ability to develop innovative technologies that solve important problems, while fostering an entrepreneurial mindset and skillset. Epicenter’s three core initiatives focus on students, faculty, and research.

Students: The University Innovation Fellows Program

The University Innovation Fellows (UIF) program for undergraduate engineering students and their peers gives students the training and support to become leaders who catalyze change on their home campuses and beyond. The Fellows, nominated by their deans and faculty, help to increase opportunities for all students to develop their creativity, design thinking, capacity for innovation and entrepreneurial mindset. As of April 2015, 291 UIFs at 115 schools have been trained to be change agents at their schools.

Faculty: The Pathways to Innovation Program

The Pathways to Innovation Program helps institutional teams of faculty and university leaders transform the experience of their undergraduate engineering students. Over a two-year process, these teams learn ways to fully incorporate innovation and entrepreneurship into a range of courses as well as strengthen co- and extra-curricular offerings. As of April 2015, 12 schools are taking part in the first cohort of the Pathways program (2014-2016) and 25 schools are taking part in the second cohort (2015-2017).

Research: Fostering Innovative Generation Studies

The Epicenter research initiative encompasses several large, multi-method, national studies of entrepreneurship and innovation in engineering collectively known as the Fostering Innovative Generations Studies (FIGS). As part of FIGS, the research team is pursuing four major research questions (RQs) that focus on program models², engineering students’ interests and goals³, curriculum development⁴, and research community building. To advance the community building effort, the research team communicates regularly with a wide variety of stakeholders to inform them of Epicenter activities and offer research-based perspectives and events that support the efforts of students, faculty, and leaders in Epicenter’s programs.

Through meetings such as the Research Summit, Epicenter strengthens the community of scholars engaged in entrepreneurship education research and contributes to national knowledge of the topic within the context of engineering education.

Section 3: Epicenter Research Summit Design

The Summit was envisioned as an opportunity to bring together individuals who study, teach, and/or develop practices and policies around I&E, in the context of either engineering education or higher education more broadly. The format — a series of themed, interactive sessions over a two-day time period — was meant to allow for deep conversation and movement towards building a research agenda in this space. The Summit was planned by a dedicated team of Epicenter researchers (Epicenter Co-PI Sheri Sheppard and research staff Drs. Shannon Gilmartin and Helen Chen of Stanford University), alongside a group of expert co-hosts (Dr. Nathalie Duval-Couetil of Purdue University, Drs. Anne Colby and William Damon of Stanford University, and Dr. Mary Besterfield-Sacre of University of Pittsburgh).

3.1 Summit Goals and Design

The Summit was designed to achieve one overarching goal and four supporting sub-goals. The overarching goal was to “Convene individuals who are actively involved in I&E education and research in order to learn from one another, discuss opportunities, and lay the groundwork for a unifying research agenda.”

The four sub-goals were to:

1. Create an event format for researchers and thought-leaders that allows them to develop connections
2. Actively share ideas and insights
3. Identify missing pieces and new opportunities
4. Imagine next steps

Below, we describe the design decisions made and methods employed to meet each sub-goal. We cite external evaluation data that help to show how these sub-goals were achieved. Then, Section 4 provides a summary and analysis of content generated at the Summit, and Section 5 provides a discussion of emergent research areas and associated partnerships and projects to pursue in the future. We conclude in Section 6 with comments on our overarching Summit goal and recommendations for the next phase of both research and community building.

Sub-goal 1: Create an event format for researchers and thought-leaders that allows them to develop connections

The first step in creating this event format was compiling a diverse list of invitees. Over a seven-month period in 2013-14, personalized save-the-date and invitation emails were sent to select individuals who were involved in entrepreneurship education research and/or practice. In the aggregate, these individuals represented a range of disciplines (e.g., business, education, engineering, sociology), sectors (e.g., postsecondary education, private industry, government), and roles (e.g., undergraduate and graduate students, faculty members, academic administrators, program officers, chief executives). These individuals were either personal contacts (individuals whom we had met prior to or through Epicenter activities) or suggested to us by other invitees. This process resembled chain-referral data collection methods in social science research.⁵

Design-wise, once our attendee list came into shape, we structured our agenda such that all attendees were placed on a single, unitary track of sessions, as opposed to having parallel session tracks that attendees would choose from as they engaged in the meeting. The intent was to strengthen connections through shared experiences. The Summit was held in a large studio space over the two days, breaking only for all-group lunches and dinners. Attendees were pre-assigned to one of 12 tables in the studio space; the assignment methodology was meant to allow people from different institutions and in different roles to sit next to one another. We note that among those attending, the majority of attendees were involved in or familiar with engineering education in some way; how entrepreneurship or innovation played into their work varied, as did their professional titles and perspectives.

The event started with the “Orientation-Disorientation-Reorientation” session, which included lunch and opening remarks from an Epicenter Research Team leader who described the purpose of the gathering. Later in the afternoon, the hosts launched a series of panel sessions. Each session was convened around a theme aligned with the FIGS research questions, i.e., “students,” “programs,” and “curriculum.”⁶ The panels featured a moderator who was a content-area expert and three to four panel members who were content-area expert scholars or practitioners, selected on the basis of biographical and research statements that each attendee provided as part of the Summit registration process.

Table 1 shows the central questions around which panelists were asked to organize their comments, by session (names and affiliations of all presenters are included in the Summit agenda in Appendix A). Because group input was a key objective, almost half of each panel session was devoted to Q&A with the audience. Detailed session notes capture the conversations for these and all sessions at the Summit.⁶

Table 1. Research-Based Panel Sessions at the Epicenter Research Summit

Session Title	Central Questions for Panelists
Research on Students’ Entrepreneurial Development and Pathways	<i>How can we learn about students’ entrepreneurial development through an interactive lens, i.e., the interplay between individual characteristics and contexts? How diverse are students’ entrepreneurial pathways? What are the implications for entrepreneurship education?</i>
Research on Entrepreneurship Programming and Unprogramming	<i>What drives entrepreneurship programming? What roles have students played in advancing capabilities in and commitments to entrepreneurship in universities, with what implications for programs? What assessment tools are most effective in evaluating program impact?</i>
Research on Curricular Approaches	<i>What works in teaching entrepreneurship, and how do we know it works? Which student populations do different approaches address? What are the top priorities or concepts in teaching entrepreneurship to engineering (or all) students?</i>

Before closing remarks on Day 2, a “keynote panel session” was held. The panel included Karl Vesper, a veteran researcher in entrepreneurship education from the University of Washington; Susan Brennan, Chief Operations Officer of Bloom Energy and Epicenter Board member; and Phil Weilerstein, President of VentureWell and Deputy Director of Epicenter. This closing panel discussed the rationale for Epicenter, the evolution of the field of entrepreneurship education, and ways that research insights could help engineering students face the “real world” after graduation. The keynote panel was hosted by Epicenter PI Tom Byers, and again, a significant portion of the session was devoted to Q&A.

Sub-goal 2: Actively share ideas and insights

In addition to the Q&A portions of the panel sessions, all attendees were invited to share their ideas and insights by designing and presenting a poster at the event. The organizers provided a poster template that designated spaces for a short biographical statement, research questions that attendees were engaged with or interested in addressing, attendees’ areas of expertise that could be integrated into Summit activities and conversations, inspirational references and resources, and desired Summit expectations and takeaways. Attendees were encouraged to use any format that would allow them to feature their individual or collaborative work on any part of entrepreneurship education, with the ultimate goal being to encourage connections with other attendees. It was not required to have research presented on the posters, since several attendees were not research scientists. The majority submitted posters, which are archived in an online gallery.⁷

To spark conversations, a 90-minute period after the opening lunch was designated for a “poster walk,” where attendees circulated and struck up conversations with poster authors (posters had been affixed to the surrounding walls and clustered by themes consistent with the panel sessions). Attendees were pre-assigned into two poster groups, allowing for one group to stand by their posters, while the other circulated, and vice versa. Attendees were assigned the task of leaving sticky notes with their name and a comment on two posters; the intent of comments was to share individual insights and indicate interest in talking further. Based on the number of sticky notes on posters and the liveliness of poster conversations, we concluded that these posters were an effective means of introducing attendees to one another and stimulating discussion.

Lunchtime roundtables on Day 2 provided another opportunity for participants to share ideas and insights. At the end of Day 1, attendees were asked to complete a short “mid-point evaluation survey” (administered by Epicenter’s external evaluators SageFox Consulting Group) that included questions about attendees’ takeaways and “top of mind” thoughts having participated in the first segment of the Summit. Attendees’ responses were analyzed that evening; the issues that emerged (based on coding and counts) became the basis for seven roundtables during the lunch on Day 2. These issues were:

- Evidence of Success of Entrepreneurship Education Faculty Development Around Entrepreneurship Education
- Research 101
- Sustaining Our Community After the Summit
- Turning Barriers to Entrepreneurship Education into Opportunities
- Understanding an Engineer’s Perspective on I&E
- Using Surveys to Understand Student Behavior

Sub-goals 3 and 4: Identify missing pieces and new opportunities and imagine next steps

To address sub-goals 3 and 4, two sessions specifically devoted to “research opportunity recognition” and “imagining next steps” were interspersed with the panel sessions. The first such session, at the end of Day 1, was designed and hosted by a group of students who are part of Epicenter’s UIF program. In this session, UIFs led small clusters of attendees in an interactive brainstorming exercise about ways to collaborate with students as research partners and participants. These clusters used white boards to capture their ideas.

The second such session was held towards the end of Day 2; this session was known as the Re3 session (Re-cap, Re-flect, Re-search). This was another highly interactive session that was divided into three parts:

1. Re-cap: Attendees documented their Summit takeaways so far on an assignment titled the “AHA” sheet (see Appendix B).
2. Re-flect: Attendees began to situate their takeaways in the context of learning theory (see Appendix C).
3. Re-search: Attendees engaged in an exercise to generate new research questions on the basis of Summit takeaways and visualize what steps they would need to take to realize this research (e.g., which partnerships were needed in the proposed research).

This last exercise was captured in what is known as the Re-search Worksheet or “Worksheet” for short (see Appendix D). The Worksheet led attendees through an iterative research-defining process where they posed a question, considered the significance of and methods for addressing the question, and then revised the question and connected it to learning theory principles. The primary data for the current paper draw from attendees’ entries on this Worksheet, as described in Section 4.

3.2 Post-Summit Assessment

As part of evaluating the Summit’s success in achieving its goals, Epicenter’s external evaluation partner, SageFox Consulting Group, invited Summit attendees to complete an online survey one week after the Summit. The survey was available from August 12 to 30. Overall, the Summit was very well received, and the high response rate (72%) from participating researchers and educators is an indication of the high level of enthusiasm and interest attendees had around dedicating time to focus on their (research) questions together and from a variety of perspectives. (We note that the response rate among graduate student attendees was lower, suggesting that there is an opportunity to engage graduate students in the development and assessment of events such as the Summit using different types of methods.)

According to the evaluation survey data, which is archived in an online report⁸, the Summit was most effective in increasing awareness, including increased knowledge of the important research questions in engineering education (sub-goal 2); 86% of respondents reported that the Summit enhanced their knowledge of important questions of the field.

The Summit format also seemed effective in creating an event space for researchers and thought-leaders that allowed them to develop connections (sub-goal 1); 86% of respondents reported that the Summit had affected their sense of the value of a research community around entrepreneurship and innovation in engineering education, and over 70% reported that the Summit made them aware of what is important to researchers and helped them to form new relationships and collaborations.

Sub-goals 3 (missing pieces) and 4 (next steps) are future focused. To this end, the evaluation survey asked attendees about how the Summit affected their work and thinking. More than half (55%) of respondents reported that the Summit influenced their current or future research or practice, and 50% indicated that the Summit influenced their ways of thinking about how to connect to researchers. Slightly fewer (some 40%) felt that the Summit affected their thinking about how to connect with educators and entrepreneurs, and helped them to become aware of what is important to entrepreneurs. While we might have hoped that even more attendees would report that their research and thinking was influenced by the Summit, we are encouraged that more than half report that a two-day event is likely or very likely to have influence.

Importantly, Summit attendees strongly supported the ideas of continuing to discuss research questions with other attendees (73%), creating thought-pieces (71%), and working on a major publication (68%). Even more so, respondents were interested in participating in a second Summit (77%) and collaborating on new research proposals with other attendees (77%). About three-quarters reported strong interest in presenting at the 2015 American Society for Engineering Education (ASEE) conference. Attendees' interest in these future connections and events informs the subsequent discussions in this paper, particularly around next steps for emergent research areas in Section 5.

Section 4: Topics Discussed at the Summit, Themes Identified

Over the two days of the event, Summit attendees viewed and discussed posters, heard and questioned panelists, and engaged in session exercises. Based on session notes, topics of discussion included program development and implementation, the definition of an “entrepreneurial mindset,” strategies for affecting change in large organizations, and many others.

For example, in the session co-organized with students from the UIF program (Session B, Appendix A), two main threads were offered for discussion by attendees: (i) the potential effects of introducing I&E opportunities early on in the pathway of engineering students; and (ii) the potential role of students as change agents who can foster and accelerate the introduction of I&E in engineering education.

These two threads appeared later in the AHA exercise. Here, attendees delved into five topic areas to gain a more thorough understanding of I&E education: students, assessment techniques, institutional ecosystems, visions for curricula, and instruction. Takeaways for attendees included the recognition of students as drivers of I&E curricular development, and questions surrounding the timing of I&E instruction (i.e., at what stage in a student's trajectory). Attendees also recognized the need for an institutional ecosystem to support and develop student I&E interests.

In looking at assessment techniques, attendees highlighted the difference between quantitatively measuring understanding as opposed to observing how students apply concepts. Attendees also highlighted the difficulty in assessing creativity, innovation, and entrepreneurship as a whole. Many called for a standardization of definitions of terms in the I&E sphere. Attendees were excited to discuss their various visions for I&E in engineering education.

All told, these UIF threads, “AHAs”, and other conversations throughout the event provided a rich background for the penultimate exercise of the Summit: the Re-search Worksheet. The

intent of the Worksheet was to consider new research questions, their significance, and methods for addressing them. This activity tied directly to Summit sub-goal 3 (identify missing pieces and new opportunities) and sub-goal 4 (imagine next steps). Below we describe our process of analyzing the Worksheet questions, then present key themes that emerged.

4.1 Data Analysis Procedures

In filling out the Re-search Worksheet, Summit attendees were articulating a research question as well as identifying why that question might be important and who might be key partners in addressing it. First, questions were transcribed, resulting in 46 questions, each authored by a different participant. Analysis focused on categorizing questions and identifying themes across the questions.

The first round of categorization, done by a single investigator, used the attendees' self-identified categorization (students, programs, curriculum), contained in the lower right-hand corner of the worksheet. These three categories followed from the topics of the three panel sessions at the Summit. Quickly, it became clear that some questions could be placed in more than one category, whereas other questions did not fit into any of the three. Part of the coding challenge was interpreting the emphasis of the question; for example, a question such as "How can students be change-agents on their campus?" could be about students, about programs that foster students being engaged as change-agents, or about institutional change (which wasn't one of the three categories).

The second round of categorization involved the identification of common elements between questions. For example, some were focused on particular learning outcomes desired, whereas others were focused on processes to achieve those outcomes. This led to a second set of categories: outcomes, ecosystems, careers, diversity and curriculum. This round of categorization was done by two investigators sequentially; first one investigator, then the other (working from the first investigator's coding), followed by discussion to come to agreement.

This second round of coding was refined by revisiting actual worksheets to better understand the context of questions, going back to some of the question-authors for clarification, and allowing for classification not just of complete questions, but also the larger issues embedded in some of the questions.

4.2 Key Themes Identified

Five themes emerged from categorizing the 46 questions that were written by Summit attendees in the "Re-search" session. These are: 1) Educational Aims, 2) Students Are Not All the Same, 3) Students' Career Pathways, 4) Educational Settings Are Not All the Same, and 5) Doing Things Differently. These themes are discussed below, and specific research questions are summarized in Table 2.

Table 2. Research Questions from the Re-search Worksheet, organized by the five theme areas

Theme	Sub-Theme	Questions
Educational Aims	High level	<ul style="list-style-type: none"> • What are the knowledge, skills, and attributes that enable an engineer to become an entrepreneur?
	Particular learning outcomes	<ul style="list-style-type: none"> • How do we help our students learn strategies for opportunity recognition? • How is self- and life-long learning promoted by working on an innovative project? • Which experiences in classroom and life prepare students to become innovators? • Do particular pedagogies generate better long-term value creation? • Do maker-spaces and communities support the creation of successful tech start-ups? • How can universities create “Δ [triangle drawn]-shaped” people?, i.e. depth of disciplinary expertise, diverse mindset, and unique passions/motivations
	I&E skills	<ul style="list-style-type: none"> • How are design and entrepreneurial mindsets similar and how are they different? What aspects are unique to each, in conflict, and the same?
	Outcome connections	<ul style="list-style-type: none"> • What are the [assessment] outcomes of engineering innovation and entrepreneurship that provide evidence of change? • How might we measure the effectiveness of University Innovation Fellows in their ecosystems?
	Assessment of impact	<ul style="list-style-type: none"> • What methods of entrepreneurial mindset learning lead to the greatest impact? • Does EEE [Entrepreneurship Education for Engineers] affect engineering recruitment and retention? • What is the relationship between entrepreneurship education and student success for engineering students? • What is the impact of informal entrepreneurship programs such as 48 hour challenges?
	Overcoming the assessment barrier	<ul style="list-style-type: none"> • How can we get beyond barriers of assessment and start looking at methods/models that programs can choose?
Students Are Not All the Same	Questions about differences	<ul style="list-style-type: none"> • How do we frame the value proposition of these essential 21st century learning (E&I)

		<p>opportunities and skills for different demographics on campus?</p> <ul style="list-style-type: none"> • What I&E curricula are most effective in generating an impact on retention in UG-engineering students by non-traditional groups? • How do we classify students studying entrepreneurship into archetypes based on their expression of how, why, and when it fits into their career trajectory? • Are active student entrepreneurs a distinct population from entrepreneurially-minded students or pre-entrepreneurs?
Students' Career Pathways	Beyond the "What and How"	<ul style="list-style-type: none"> • How does entrepreneurship education fit into [students'] career trajectory? • How do students describe barriers and opportunities to becoming entrepreneurs? • How do I help students decide if entrepreneurship could be their passion? • How can we provide incentives to engineering students to create ventures while staying in school at least part-time?
Educational Settings Are Not All the Same	Learning from others	<ul style="list-style-type: none"> • What are the common models, success sectors, and barriers amongst the world's most highly regarded programs of engineering entrepreneurship education? • What conditions need to be present in engineering education to support the development of an E&I ecosystem?
Doing Things Differently	Qualifications of faculty	<ul style="list-style-type: none"> • What traits are desirable in faculty to exhibit in order to drive an entrepreneurial mindset in students? • How to qualify professors/teachers in innovative thinking?
	Thinking innovatively about I&E research	<ul style="list-style-type: none"> • How might bringing E&I engaged students onto the research team advance progressive research? • What can we learn from social networks with regard to students' entrepreneurial intentions and persistence? • Can I replace research surveys with data mining and analysis of social network data?

Educational Aims

Questions in this category deal with I&E outcomes and learning goals. Some of the questions are at a very high level, asking which learning outcomes are appropriate for an institution to help its students achieve, for example: *What are the knowledge, skills, and attributes that enable an engineer to become an entrepreneur?*

Other questions in this category address particular, already-identified learning outcomes/goals (e.g., self-learning, opportunity recognition strategies, knowledge of business language, help-seeking), assuming that they are already accepted learning outcomes. They go on to focus on identifying what curricular, co-curricular, extra-curricular or life activities would help students achieve desired outcomes.

Also noteworthy is a question that suggests the possibility that I&E skills may be related to skills that are already part of the engineering lexicon, asking: *How are design and entrepreneurial mindsets similar and how are they different? What aspects are unique to each, in conflict, and the same?*

A few questions in this category, such as *What are the [assessment] outcomes of engineering innovation and entrepreneurship that provide evidence of change?* recognize the importance of connecting learning outcomes not only to activities, but also to assessment strategies to know if the desired outcomes have actually been achieved. And importantly, one question raises concerns about assessment being seen as a barrier to investigating new and interesting program methods and models.

Sometimes these assessment-related questions are framed around assessment of impact beyond particular learning outcomes, asking (for example), *What methods of entrepreneurial mindset learning lead to the greatest impact?*

Students Are Not All the Same

These overarching questions relate to ways desired I&E outcomes and engagement might differ given the differing characteristics, backgrounds, and interests of students. Summit attendees wanted to know, *How do we frame the value proposition of these essential 21st century learning (I&E) opportunities and skills for different demographics on campus?* and *Are active student entrepreneurs a distinct population from entrepreneurially-minded students or pre-entrepreneurs?*

Surprisingly absent are any questions that specifically look at I&E engagement in relation to students' background and academic characteristics such as gender, underrepresented racial/ethnic minority (URM) status, and/or engineering major.

Nonetheless, these questions are particularly noteworthy because they recognize hard-learned lessons in other areas of engineering education reform. They acknowledge that students' motivation and interests are highly individualized, and that how and what we teach are equally important in drawing students to engineering. It is important to consider how such differences influence the success of any educational reform.

Students' Career Pathways

The Summit's last session focused on the evolution of the I&E research field in engineering education and the landscape of research challenges and opportunities. Some of the questions posed in the Worksheet went beyond asking about the "what and how" of learning I&E skills, abilities, and attitudes, to asking about the relationship of entrepreneurship education to career plans and success, considering, *How does entrepreneurship education fit into [students'] career trajectory?*

Career-related worries expressed by Summit attendees in their questions include, *How do I help students decide if entrepreneurship could be their passion?* and *How can we provide incentives to engineering students to create ventures while staying in school at least part-time?*

None of the questions consider how entrepreneurial skills might serve graduates as they move into established firms, companies and organizations, or in undertaking social entrepreneurship activities. It is unknown exactly how (or whether) I&E skills are useful in all engineering workplaces, or whether people assume that its value primarily applies to the start of new ventures.

Educational Settings Are Not All the Same

Some questions imply that desired outcomes, as well as implementation details, may be school dependent given their particular and varied characteristics, environments, and stakeholders. Still, several of the Worksheet questions clearly acknowledge that learning from other schools is valuable, asking, *What conditions need to be present in engineering education to support the development of an I&E ecosystem?*

Doing Things Differently

Attendees posed questions relating to how innovative thinking might be brought to I&E educational practice itself, both in terms of educational strategies used and the individuals carrying out these strategies. For example, one idea raised is how to engage students not just as customers of new programming and courses, but instead as "change-agents" in higher education and in research. The qualifications of faculty teaching I&E topics was also questioned, asking, *How to qualify professors/teachers in innovative thinking?* This perhaps reflects an underlying belief that standard tenure-line or tenured faculty may not always be the best educators in these domains.

In addition, some questions focus on the use of innovative, non-standard curricular approaches such as "informal e-programs," "role models," and "building and prototyping," and the impact of these on I&E learning. To this list we would also add entrepreneurship dorms, student maker spaces, student competitions, campus or school innovation centers, entrepreneurship events, student clubs, and many more.

Finally, attendees posed questions about how innovative thinking might be brought to I&E educational research itself, asking how I&E engaged students might contribute to a research team and how novel data collection methods might be created.

Section 5: Major Research Areas Emerging from the Summit: Next Steps

In analyzing the five themes, it became clear that these could be further grouped into three major research areas, given the commonalities in units of analysis and the relationships with other emphases in engineering education research. These three areas are labeled **Linking Outcomes to Reform**, **Understanding Student Diversity**, and **Examining Contexts**. Below, we expand on each area, posing a few new questions in italics, and then suggest ways that the research in these areas can unfold.

Linking Outcomes to Reform. The theme labeled “Educational Aims,” which encompasses questions about the learning goals and outcomes for students in I&E settings, arguably falls into a broader conversation about engineering education reform. That is, once we start asking about the goals of entrepreneurship education for engineers (or about the means to achieve these goals), we almost inevitably move into questions about the goals of engineering education, and how we can continue to refine and improve it in light of changing social, economic, and technological contexts. Conversely, calls for broader reform often begin with identifying the outcomes and environments of engineering education as it is currently designed and practiced, and then imagining and implementing new types of educational settings for engineers that realize learning outcomes in new ways. *Where does I&E fit into engineering education’s imagination? How can assessment strategies support connections between engineering education and entrepreneurship/innovation education as both evolve?*

Understanding Student Diversity. The two themes “Students Are Not All The Same” and “Students’ Career Pathways” together form the basis for the second major research area: student diversity in entrepreneurship education in engineering. Attendees provided several driving questions for this area. Building on these, other questions include the following: *Not all engineering students are attracted to I&E for the same reasons; how does this come into play in framing learning goals? Graduates will take on a variety of engineering and non-engineering related professional jobs; how do I&E skills play roles in these various jobs (and what are the implications in how these skills are taught)?* The roles of student diversity and the impact of diversity on learning have been the subject of much study in higher education generally; it is an exciting time to probe these questions in I&E spaces in engineering.

Examining Contexts. “Educational Settings Are Not All The Same” and “Doing Things Differently” in essence speak to the importance of contextual characteristics when considering students’ experiences and outcomes, whether these are curricular, pedagogical, and faculty characteristics or programmatic or systemic characteristics. These types of characteristics are the “bread and butter” of educators as they design new spaces, figuratively and literally, within which their students can learn. Building on attendees’ questions, sample lines of future inquiry include: *Not all schools will have the same I&E learning goals for their engineering students, as the larger “ecosystem” of the school comes into play; how can a school identify their own appropriate learning goals? Further, how might I&E play a role in the actual development of programs and resources—for example, using novel and unconventional means to build innovative programs on innovation?*

Below, we discuss strategies for moving research in these three areas forward—namely, learning from and drawing on previous research, collaborating with stakeholders, and developing foundational white papers.

Research Findings to Build On

Previous research can be drawn into and inform conversations on the identified areas. Table 3 provides a starting list of such research. Note that in the area of “Understanding Student Diversity,” we should be considering not only research findings focused on understanding the roles of diversity in I&E education,^{3,9} but also research relating to how diversity affects higher education more generally.^{10,11,12} The same can be said for each of the other areas, as there is much to learn from studies of other or broader change initiatives in higher education.

Table 3. Research that informs each of the major areas: A starting list

Area	Citations
Linking Outcomes to Reform	Bilen et al. ¹³
	Byers et al. ¹
	Creed et al. ¹⁴
	Duval-Couetil ¹⁵
	Duval-Couetil, Kisenwether et al. ¹⁶
	Jamieson and Lohman ¹⁷
Understanding Student Diversity	Brunhaver et al. ¹⁸
	Clarke and Antonio ¹⁰
	Gerba ⁹
	Hill et al. ¹¹
	Jin et al. ³
	Scutt et al. ¹²
	Sheppard et al. ¹⁹
Examining Contexts	Besterfield-Sacre, Özaltin et al. ²⁰
	Besterfield-Sacre, Shartrand, and Zappe ²¹
	Bodnar et al. ²²
	Duval-Couetil, Shartrand, and Reed-Rhoads ²³
	Gilmartin et al. ²
	Graham ²⁴
	Özaltin et al. ²⁵
	Shartrand et al. ²⁶
Zappe et al. ²⁷	

The Need for Collaboration

Clearly, some of the questions developed in the Re-search Worksheet exercise are very ambitious and/or could not be addressed by research being done in isolation from the broader contexts of I&E. Answering these questions requires partnerships and collaboration between researchers, engineering faculty, university administrators, students, practitioners in the

corporate/non-profit/government worlds, policy makers and professional societies. For example, in addressing many of the questions under the area of “Linking Outcomes to Reform,” engineering faculty, university administrators, and practitioners are arguably best positioned to identify which core I&E skills should support and enrich the mission of engineering education. Research can provide a sound foundation for the conversation by providing a deep understanding of what skills are linked to entrepreneurial success in a variety of professional settings, from start-ups to established companies⁴, and how these skills are cognitively and affectively related to other skills and abilities expected of engineering graduates. Policy makers and professional societies can align I&E education to national needs for engineering talent and advocate for identified skills to become part of professional standards.¹⁶

Another example of the necessary collaboration between researchers and practitioners in the corporate/non-profit/government worlds is to address questions that emerged under the area of “Understanding Student Diversity.” Such collaboration could assist faculty and university administrators in designing programming, helping students understand what career pathways are possible, and counseling corporate/non-profit/government entities in how to help the career trajectories of young engineers.

Foundational White Papers

Summit attendees strongly supported the idea of continuing to discuss research questions with other attendees, creating thought-pieces, and working on a major publication. One form that this writing could take is in white papers on the three major areas that emerged from the Summit. These three areas effectively set the agenda for future research on I&E in engineering education. Each white paper could map out what is known in the area as well as the key questions that need to be addressed as part of developing such research. These white papers could then become the foundational documents for practice, partnerships, and policymaking in the decades to come.

The white papers also could drive a second, potentially larger Research Summit, which attendees indicated strong interest in. Each paper could become the basis for a series of sessions that bring in not only scholars and practitioners in engineering education, but those who are doing similar types of work in business, in sociology, and in psychology (as three examples). Multidisciplinary teams could be created to begin to tackle the questions raised in the white papers. Greater involvement of both new and seasoned entrepreneurs would be welcome too, as a way to expand on or qualify the statements in the papers. These interactions even might be filmed as part of a documentary on educational innovation and change. The possibilities for a second meeting are limitless.

Section 6: Conclusions

The overarching goal of the Summit was to “Convene individuals who are actively involved in I&E education and research in order to learn from one another, discuss opportunities, and lay the groundwork for a unifying research agenda.” On the basis of the data in this paper, we propose that attendees were able to learn from one another, have key conversations about opportunities, and, through both collective and individual work, set the stage for the development of a new agenda. The Summit’s goals were largely achieved (a statement supported by the evaluation data), and post-event communications continue with attendees. Materials from the Summit are available on the Epicenter website²⁸, and a session at ASEE

2015, sponsored by the ENT division, is being organized around papers authored by Summit attendees.

As described earlier, possible next steps, in terms of continuing to engage and support Summit attendees and the larger I&E engineering education research community, include a second Epicenter Research Summit; over 75% of Summit attendees voiced strong interest in attending such an event. This second Summit might be organized around foundational white papers that continue to expand the conversation on how an engineering education should teach much more than technical skills.

Acknowledgements

The authors of this paper wish to thank their Epicenter colleagues for helping to realize the Research Summit and for their support of the research initiative. We also are grateful to our imaginative, dedicated, enthusiastic, and wise Summit attendees and co-hosts, without whom starting to co-develop a research agenda for the future would not be possible. We very much appreciate the helpful comments provided by reviewers of earlier drafts of this paper. This material is based upon work supported by the National Science Foundation under Grant No. 1125457.

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EPICENTER research summit

AUGUST 4-5, 2014 • STANFORD UNIVERSITY

AGENDA

MONDAY, AUGUST 4

Peterson Laboratory (Building 550), Stanford University

(Peterson is the home of the d.school and the Design Group of Mechanical Engineering)

Time	Location	Event Details
11am – 12pm	Outside Peterson on Panama Mall	Registration
12pm – 1pm	Atrium	Lunch Session 0: Orientation-Disorientation-Reorientation <i>Host:</i> <i>Sheri Sheppard, Epicenter, Stanford University</i>
1pm – 2pm	Room 200	Poster walk
2pm – 2:15pm	Outside Room 200	Break with refreshments
2:15pm – 4pm	Room 200	Session A: Research on Students' Entrepreneurial Development and Pathways <i>How can we learn about students' entrepreneurial development through an interactive lens, i.e., the interplay between individual characteristics and contexts? How diverse are students' entrepreneurial pathways? What are the implications for entrepreneurship education?</i> <i>Session chairs:</i> <i>Anne Colby, Stanford University</i> <i>Bill Damon, Stanford University</i>



Stanford
University



Panelists:

*Dan Ferguson, Purdue University
Kathryn Jablokow, Pennsylvania State University
Heather Malin, Stanford University
Tenelle Porter, Stanford University
Gisele Ragusa, University of Southern California
Sarah Zappe, Pennsylvania State University*

4pm – 5:30pm Room 200

Session B: Cooking Up New Research Ideas: With Students,
About Students

Students can be so much more than recipients of their education and research subjects. In this interactive session, join students from Epicenter's University Innovation Fellows (UIF) program to work collaboratively in envisioning new research projects to understand how higher education can empower students to be innovators as well as co-designers of their education.

Session organizers:

*Leticia Britos Cavagnaro, Epicenter, Stanford University
Katie Dzigan, Epicenter, National Collegiate Inventors and Innovators Alliance (NCIIA)
Humera Fasihuddin, Epicenter, National Collegiate Inventors and Innovators Alliance (NCIIA)
Hristina Milojevic, University Innovation Fellow, Union College
Breanne Przestrzelski, University Innovation Fellow, Clemson University
Gurloleen Rathore, University Innovation Fellow, Texas A&M University
Ben Riddle, University Innovation Fellow, Furman University
Elliot Roth, University Innovation Fellow, Virginia Commonwealth University
Valerie Sherry, University Innovation Fellow, University of Maryland
Gregory Wilson, University Innovation Fellow, University of Georgia*

5:30pm – 6:30pm Room 200

Poster walk and midpoint reflections

6:30pm – 8pm Corner of Lomita
Drive and Santa
Teresa

Outdoor BBQ dinner

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TUESDAY, AUGUST 5

Peterson Laboratory (Building 550), Stanford University

(Peterson is the home of the d.school and the Design Group of Mechanical Engineering)

Time	Location	Event Details
8am – 8:45am	Outside Room 200	Breakfast
8:45am – 9am	Room 200	Day 2 opening remarks <i>Host:</i> <i>Sheri Sheppard, Epicenter, Stanford University</i>
9am – 10:30am	Room 200	Session C: Research on Entrepreneurship Programming and Unprogramming <i>Overarching Questions: What drives entrepreneurship programming? What roles have students played in advancing capabilities in and commitments to entrepreneurship in universities, with what implications for programs? What assessment tools are most effective in evaluating program impact?</i> <i>Session chair:</i> <i>Mary Besterfield-Sacre, University of Pittsburgh</i> <i>Panelists:</i> <i>Ruth Graham, RH Graham Consulting Limited</i> <i>Doug Melton, Kern Family Foundation</i> <i>Helmut Schoenenberger, Technical University Munich</i>
10:30am – 10:45am	Outside Room 200	Break with refreshments
10:45am – 12:30pm	Room 200	Session D: Research on Curricular Approaches <i>Overarching Questions: What works in teaching entrepreneurship, and how do we know it works? Which student populations do different approaches address? What are the top priorities or concepts in teaching entrepreneurship to engineering (or all) students?</i> <i>Session chair:</i> <i>Nathalie Duval-Couetil, Purdue University</i>

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Panelists:

*Erin MacDonald, Stanford University
Sabrina Niederle, Technical University Munich
Mark Schar, Epicenter, Stanford University
Angela Shartrand, Epicenter, National Collegiate Inventors and
Innovators Alliance*

12:30pm – 1:30pm Atrium

Lunch and roundtable sessions

1:30pm – 3pm Room 200

Session E: Re³ – Re-cap, Re-flect, Re-search

In this interactive session, attendees will review what they have discovered at the Summit, integrate theories of student learning into their thinking, and generate exciting, breakthrough ideas for research.

Session chairs:

*Mark Schar, Epicenter, Stanford University
Angela Shartrand, Epicenter, National Collegiate Inventors and
Innovators Alliance
Sheri Sheppard, Epicenter, Stanford University*

3pm – 3:15pm Outside Room 200

Break with refreshments

3:15pm – 4:45pm Room 200

Session F: Keynote Panel: Forest-Level Reflections on the Research Landscape

Moderator:

*Phil Weilerstein, Epicenter, National Collegiate Inventors and
Innovators Alliance*

Panelists:

*Susan Brennan, Bloom Energy
Tom Byers, Epicenter, Stanford University
Karl Vesper, University of Washington*

4:45pm – 5pm Room 200

Closing remarks

Host:

Sheri Sheppard, Epicenter, Stanford University

5pm – 5:15pm Atrium

Group photo

5:15pm – 7pm Garage/Outdoors

Drinks and hors d'oeuvres

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APPENDIX B

In this worksheet, Epicenter Research Summit attendees documented their takeaways from the “Re-cap” portion of Session E: “Re-cap, Re-flect, Re-search.” In the last column, attendees were asked to provide an “AHA” big thought or idea.


Session E: Re-Cap		 EPICENTER research summit <small>AUGUST 4-5, 2014 • STANFORD UNIVERSITY</small>	
Your Name: _____			
Topic Areas	I Like What did you like about this Session?	I Wish What did you wish was discussed ... that was not?	AHA! What is a Big Thought or Big Idea from this Session?
Students Session A & B <i>Entrepreneurial development, pathways, research ideas</i>			
Programs Session C <i>Research on Entrepreneurship Programming and Unprogramming</i>			
Curriculum Session D <i>Research on Curricular Approaches</i>			

Process:

- On your own, think back to the Sessions. Capture your thoughts as “I Like” and “I Wish,” then a new thought ... **your AHA!** (5 minutes)
- As a table, share your AHAs! Place your stars on AHAs you like. Re-write or create new AHAs! (10 minutes)
- As a table, pick three AHAs that are your favorite, write each of them on a separate piece of paper provided, and we will talk about them as a Group (15 minutes)

APPENDIX C

In this worksheet, Epicenter Research Summit attendees documented their takeaways in the context of learning theory from the “Re-reflect” portion of Session E: “Re-cap, Re-reflect, Re-search.”

Session E: Re-reflect		 EPICENTER research summit AUGUST 4-5, 2014 • STANFORD UNIVERSITY
Your Name: _____		
Learning Theory Micro-Lecture How Learning Works Susan Ambrose UNDERSTANDING THE STUDENT – BACKGROUND AND MOTIVATION <ul style="list-style-type: none">• Students' prior knowledge can help or hinder learning• How students organize knowledge influences how they learn and apply what they know• Students' motivation determines, directs, and sustains what they do to learn• Students' current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning THE STUDENT INTERACTING WITH THE MATERIAL <ul style="list-style-type: none">• To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned• Goal-directed practice coupled with targeted feedback enhances the quality of students' learning• To become self-directed learners, students must learn to assess the demands of the task, evaluate their own knowledge and skills, plan their approach, monitor their progress, and adjust their strategies as needed	Notes: Thoughts and Reflections on Learning Theory	Notes: Thoughts and Reflections on the AHAs!

APPENDIX D

Using this worksheet, titled “Worksheet #3,” Epicenter Research Summit attendees engaged in an exercise to generate new research questions on the basis of Summit takeaways and visualize what steps they would need to take to realize this research. This took part in the “Re-search” portion of Session E: “Re-cap, Re-reflect, Re-search.”

Session E: Re-search

Your Name: _____

Ladder of Abstraction
S.I. Hayakawa

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Why? So that we might ...

... and why is that important?

Why? In order to ...

... and why is that important?

What is your research question?

★

... and how would I do that?

How? By ...

... and how would I do that?

How? Or by ...

Three Word Title:

What is your research question?

●

Why is this an important question?

How does it connect to goals, motivation and/or feedback?

What partners do you need in this research?

How would you categorize your research question?
Choose only ONE answer:

Students
 Programs
 Curriculum

Process:

- On your own, think of a research question that you would like to answer from this Summit. Write it in the center box on the left. Move up the ladder with “and why is that important” and down the ladder with “and how would I do that?”
- Review your thoughts, then re-write your research question. Answer a few prompts about this question. (10)