Students in entrepreneurship programs gain insights into designing for end users, working in and managing interdisciplinary teams, communicating effectively, thinking critically, understanding business basics, and solving open-ended problems.

Entrepreneurship
Its Role in Engineering Education

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It is an exciting time to be an engineer. In recent decades, the engineering workforce has helped the United States make substantial advances in communications, health, defense, infrastructure, and manufacturing (Blue et al. 2005), and the time between the emergence of new technologies and their implementation has steadily declined (Kurzweil 2001). Opportunities and challenges continue to require engineers to literally invent the future by developing breakthrough technologies that solve global problems and enhance the quality of life.

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Ongoing innovation is required to address pressing problems and to maintain America's global competitiveness, and engineering is the foundation of much of that innovation. To be prepared to enter the workforce and thrive in this ever changing global economy, engineers need to be able to collaborate effectively as leaders, in teams, and with their peers. In addition to their technical and analytical expertise, they need to be flexible, resilient, creative, empathetic, and have the ability to recognize and seize opportunities (NAE 2004; Sheppard et al. 2008). All of these skills can and should be taught to engineers as part of their formal education. It is thus the responsibility of engineering educators to instill these qualities in students to enable them to be more innovative and entrepreneurial.

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In this article, we examine the importance of entrepreneurship efforts in engineering education, national support for entrepreneurship, student and faculty attitudes and engagement, noteworthy programs, and early research on these initiatives. We then offer our perspective on the future landscape for innovation and entrepreneurship in engineering education.

The Importance of Entrepreneurship Education

It is no longer enough to come out of school with a purely technical education; engineers need to be entrepreneurial in order to understand and contribute in the context of market and business pressures. For engineers who start companies soon after graduation, entrepreneurship education gives them solid experience in product design and development, prototyping, technology trends, and market analysis (Nelson and Byers 2010). These skills are just as relevant for success in established enterprises as they are in startups; students with entrepreneurial training who join established firms are better prepared to become effective team members and managers and can better support their employers as innovators.

Entrepreneurship education teaches engineering students in all disciplines the knowledge, tools, and attitudes that are required to identify opportunities and bring them to life. Students who take part in entrepreneurship programs as undergraduates gain insights not available from traditional engineering education, such as understanding and designing for end users ("empathy"), working in and managing interdisciplinary teams, communicating effectively, thinking critically, understanding business basics, and solving open-ended problems (ABET 1995; NAE 2004).

Expanding Support for Entrepreneurship

In many universities, entrepreneurship is no longer confined to business schools. In fact, it is one of the fastest growing subjects in undergraduate education overall, with formal programs such as majors, minors, and certificates quadrupling from 1975 to 2006 (Brooks et al. 2007).

And interest in entrepreneurship extends beyond higher education. In recent decades, technology entrepreneurs have become American heroes, and the entrepreneurial process has been embraced as a key element of the country's future success and global leadership. The White House has emphasized entrepreneurship as a means of driving innovation: in addition to improving STEM education, President Obama's strategy for American innovation calls for an investment in high-growth and innovation-based entrepreneurship to drive the US economy (NEC 2011).

The National Science Foundation has also invested in entrepreneurship and innovation with programs such as Innovation Corps (I-Corps), which prepares scientists and engineers to consider broader opportunities for their technology and research, and the National Center for Engineering Pathways to Innovation (Epicenter). Managed by Stanford University and the National Collegiate Inventors and Innovators Alliance (NCIIA), Epicenter was established in 2011 to expand the infusion of entrepreneurship into undergraduate engineering education. It sponsors initiatives that inspire engineering students to envision possibilities and create viable, innovative products, services, and processes.[1]

[1] Information about Epicenter programs and resources is available online at http://epicenter.stanford.edu/.

Student and Faculty Attitudes toward Entrepreneurship Education

Unlike other changes to the engineering curriculum that have been implemented with little student input, there is substantial and growing student demand for entrepreneurship education. In an annual survey of American college freshmen, 41 percent of respondents said that "becoming successful in a business of my own" is an objective they considered "essential" or "very important" (Pryor et al. 2012). In a study of engineering students by Duval-Couetil and colleagues (2012), two-thirds of the respondents agreed that entrepreneurship education would broaden their career prospects and choices.

Among faculty and administrators, according to a recent ASEE survey, about 50 percent of respondents reported that access to entrepreneurship programs is important for their engineering undergraduates (Peterfreund 2013). While this might be interpreted as a discouraging statistic for the expansion of entrepreneurship in education, we view it as an opportunity.

Working with faculty members will help the Epicenter team understand their points of view and give us tools for influencing others. For example, it may be that some faculty members do not have experience in entrepreneurship and do not really understand it (Zappe et al. 2013). For others, it may be that their perception of their students' needs and challenges puts entrepreneurship low on the priority list of learning objectives. Furthermore, survey findings suggest that faculty perceptions about overcrowded engineering curriculum, and their belief that faculty peers and administrators are unsupportive of including entrepreneurial learning objectives in engineering education, contribute to making these objectives a low priority for engineering undergraduate programs (Peterfreund 2013).

Both in and outside the classroom, learning to be an entrepreneur requires a complex set of knowledge, skills, and abilities (Nelson and Byers 2010). The recent work of Zappe and colleagues (2013), which examined the beliefs of faculty who teach entrepreneurship to engineering students, is a first step toward understanding faculty perspectives on entrepreneurial skills and codifying, organizing, and advancing engineering undergraduate entrepreneurial learning objectives. Their study found that educators who teach entrepreneurship to engineering students believe that:

- The defining characteristic for an entrepreneur is the ability to act on opportunities. Other key characteristics are drive, passion, resourcefulness, and the belief that one can be successful.
- The characteristics of an entrepreneurial mindset can be learned, including the ability to act on opportunities, learn from failures, and solve problems, as well as technical, business, interpersonal, and communication skills.
- The way educators teach entrepreneurship is deeply influenced by their own career experiences as well as their beliefs about how people become entrepreneurs.

Understanding the beliefs of those who currently teach entrepreneurship is useful in defining the educational outcomes for entrepreneurial learning. These beliefs also suggest that more work is needed to enhance understanding of the relationships between teaching strategies, personal experience with entrepreneurship, and effectiveness in achieving learning outcomes.

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Faculty Engagement and Impacts

The integration of entrepreneurship and innovation in engineering education will require a shift in thinking and willingness on the part of faculty to participate in, or at least accept changes in, the engineering curriculum. Recent experiences in introducing new approaches to engineering education are a good indicator of the challenges and a guide to which approaches will be effective.

In a study of adoption of several major educational innovations in engineering education, Borrego and colleagues (2010) found that a combination of approaches was needed to build awareness, support practical adoption, and enable institutionalization. Developing well-defined and proven materials is necessary but not sufficient. Best practices and training opportunities need to be complemented by awareness and buy-in among faculty and administrators, and the provision of resources and incentives for implementation. Importantly, the highest adoption rates were found for innovations that

could be implemented by individuals or small teams without a great deal of departmental coordination.

Engaging traditional engineering faculty is, however, only part of the picture, since many of those who teach entrepreneurship are clinical, adjunct, or nontraditional faculty. Therefore, curricular and noncurricular program development needs to take account of the advantages and challenges in terms of a school's faculty makeup.

Models of Engineering Entrepreneurship Education

A mixture of approaches to entrepreneurship education is necessary to deliver the experiences and knowledge that lead to innovative and entrepreneurial graduates. Fortunately, with high interest in entrepreneurship among students, there is an opportunity to catalyze student awareness and interest through short, engaging experiences. To that end, Epicenter is building on the success of NCIIA's Invention to Venture workshops by training and deploying "student ambassadors" at a number of institutions, where they hold events, run competitions, and exemplify the path toward becoming an innovator.

Successful student innovators become powerful role models for their classmates.

Also key will be thinking in new ways about how to approach entrepreneurship education. Some engineering schools have formal certificate and minors programs in entrepreneurship for their undergraduates, and 50 percent of faculty respondents to the ASEE survey reported that extracurricular programs are a prevalent means for engineering students to gain experience in entrepreneurship (Peterfreund 2013). The proportion of students participating in these experiences is still small, but their impact on the participating students and in inspiring their peers is important. Successful student innovators become powerful role models for their classmates.

Neck and Greene (2011) call for expanding concepts of teaching entrepreneurship from a process-based approach with known inputs and outputs to a methods-based approach that supports iteration and creativity. Others are thinking about the incorporation of entrepreneurship modules in which engineering problem solving takes place in the context of a business opportunity.

The emergence of online learning resources has been particularly useful for delivering digital content both in and out of the classroom. For instance, the Stanford Technology Ventures Program's Entrepreneurship Corner (ECorner) offers thousands of video clips that are easily incorporated in classroom discussions, student research, and presentations. Epicenter is building on the success of ECorner and creating small learning modules with entrepreneurship-related content. Online courses on entrepreneurship also allow faculty and students far removed from vibrant entrepreneurial ecosystems to access a wide range of instructors and content, and enable faculty to spend more time nurturing innovation.

Another high-impact approach involves creating intensive entrepreneurship programs and experiences for highly motivated students. Successful examples include the University of Texas at Austin's Idea to Product (I2P) competition, the NCIIA's E-Team program for launching student ventures, and a growing number of entrepreneurship-themed "living-learning" communities (combining student residence with curricular and extracurricular activities) at universities around the country (Inkelas et al. 2008). Students report that these programs put their engineering education in context and provide opportunities to learn about leadership in emerging and existing enterprises.

It is also important to explore commonalities between entrepreneurial skills and ABET guidelines to see how entrepreneurship can fulfill key ABET requirements. Alignment with these requirements can influence university leaders who are motivated to maintain their ABET accreditation.

Analysis of Existing Programs

A number of engineering schools have already made significant investments in programs to help their undergraduate students become skilled in entrepreneurship, and the recent work of Besterfield-Sacre and colleagues (2011; Shartrand et al. 2010) is an important step toward comprehensive analysis of such courses and programs in the United States. Their preliminary study found that the primary differentiators among these programs are "density of offerings" (coursework, extracurricular activities, minors/certificates, concen-

[2] The Carnegie Classification tracks institutional diversity in US higher education. Information is available online at http://classifications.carnegiefoundation.org/.

trations, and entrepreneurship majors), Carnegie Classification,[2] and physical and virtual spaces dedicated to entrepreneurial activities (incubators or business accelerators, web portals for campus resources, entrepreneurship research institutes, and design and prototyping spaces).

Building on this research, Epicenter has launched a study of 41 engineering schools that offer certificates or minors in entrepreneurship. The schools range in size from very small (13 engineering bachelor's degrees per year) to large (more than 1,700 such degrees). Some programs are housed in the engineering department or school (e.g., University of Pennsylvania), some are offered by the business school to students across the entire campus (e.g., University of Connecticut), and still others are partnerships between departments such as engineering and business (e.g., Rensselaer Polytechnic Institute).

A primary aim of the Epicenter study is to develop a multifaceted analysis of these offerings as a resource. Those who are designing entrepreneurship programs will be able to build on the models and experiences of others and to engage the larger engineering education community in discussions about how and why to include entrepreneurship in engineering education.

Looking Ahead

There is reason to be optimistic about the potential for infusing opportunities for entrepreneurship and innovation into engineering education. The NSF, NAE, and other engineering education supporters have invested significantly in spurring innovation in engineering education, and a growing field of engineering education researchers is studying and documenting what works, how, and why. Coupled with a well-supported approach that empowers faculty across the nation and engages both institutional leaders and accreditation bodies, this change is under way.

To continue building a movement to create more entrepreneurial engineers, we urge stakeholders in undergraduate engineering education to consider the following questions and actions.

Students: Ask questions of your professors, administrators, and fellow students. Where does entrepreneurship fit into the educational picture at your school? What opportunities already exist for you? How can you help build more opportunities?

Engineering faculty: Consider the role of entrepreneurship in all facets of your work, from teaching to research. How might the subjects you teach connect to engineering and business practice? How might your students benefit from seeing this larger context for their technical learning?

Academic administrators: Talk with your faculty, students, and alumni about their attitudes about entrepreneurship. How have elements of entrepreneurship and innovation added to their professional success? How might additional training in these elements contribute to future success?

Industry leaders and representatives: Reflect on how your operations use engineers with an entrepreneurial approach and mindset. How can you engage academic program faculty in discussions about the key entrepreneurial skills and abilities you need in your engineering workforce?

Beginning these conversations with your peers and other stakeholders can expose connections between motivated individuals and groups and yield opportunities for expanding the innovative and entrepreneurial ecosystem at your institution. With the growing support of entrepreneurship in the engineering community, we are confident that 21st century engineering graduates can and will be equipped with the ability to address the challenges of the coming decades in innovative and economically generative ways.

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References

ABET [Accreditation Board for Engineering and Technology]. 1995. The Vision for Change: A Summary Report of the ABET/NSF/Industry Workshops. Baltimore MD.

Besterfield-Sacre M, Ozaltin NO, Shartrand A, Shuman LJ, Weilerstein P. 2011. Understanding the technical entrepreneurship landscape in engineering education (AC 2011-1729). Presented at the 2011 Annual Conference and Exposition of the American Society for Engineering Education (ASEE), June 26–29, Vancouver BC.

Blue CE, Blevins LG, Carriere P, Gabriele G, Kemnitzer S, Vittal R, Ulsoy G. 2005. The Engineering Workforce: Current State, Issues, and Recommendations. Arlington VA: National Science Foundation.

Borrego M, Hall TS, Froyd JE. 2010. Diffusion of engineering education innovations: A survey of awareness and adoption rates in US engineering departments. Journal of Engineering Education 99(3):185–207.

Brooks R, Green WS, Hubbard RG, Jain D, Katehi L, McLendon G, Plummer J, Roomkin M. 2007. Entrepreneurship in American Higher Education. Report from the Kauffman Panel on Entrepreneurship Curriculum in Higher Education.

Duval-Couetil N, Reed-Rhoads T, Haghighi S. 2012. Engineering students and entrepreneurship education: Involvement, attitudes and outcomes. International Journal of Engineering Education 28(2):425–435.

Inkelas KK, Szelényi K, Soldner M, Brower AM. 2008. National Study of Living-Learning Programs: 2007 Report of Findings. Available online at http://drum.lib.umd.edu/bitstream/1903/8392/1/2007%20NSLLP%20Final%20Report.pdf.

Kurzweil R. 2001. The law of accelerating returns. Essay, March 7. Available online at www.kurzweilai.net/the-law-of-accelerating-returns.

NAE [National Academy of Engineering]. 2004. The Engineer of 2020: Visions of Engineering in the New Century. Washington: National Academies Press.

NEC [National Economic Council]. 2011. A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs. Washington.

Neck HM, Greene PG. 2011. Entrepreneurship education: Known worlds and new frontiers. Journal of Small Business Management 49(1):55–70. doi: 10.1111/j.1540-627X.2010.00314.x.

Nelson AJ, Byers T. 2010. Challenges in University Technology Transfer and the Promising Role of Entrepreneurship Education. Kauffman: Emerging Scholars Initiatives.

Pryor JH, DeAngelo L, Blake LP, Hurtado S, Tran S. 2012. The American Freshman: National Norms Fall 2011. UCLA Higher Education Research Institute.

Peterfreund AR. 2013. Epicenter Baseline Survey: Report of Findings. Available online at http://sagefoxgroup.com/epicenter.

Shartrand A, Weilerstein P, Besterfield-Sacre M. 2010. Technology entrepreneurship programs in US engineering schools: An analysis of programs at the undergraduate level (AC 2010-666). Presented at the 2010 Annual Conference and Exposition of the American Society for Engineering Education (ASEE), June 20–23, Louisville KY.

Sheppard SD, Sullivan WM, Macatangay K, Colby A. 2008. Educating Engineers: Designing for the Future of the Field. San Francisco: Jossey-Bass.

Zappe S, Hochstedt K, Kisenwether E, Shartrand A. 2013. Teaching to innovate: Beliefs and perceptions of instructors who teach entrepreneurship to engineering students. International Journal of Entrepreneurship Education 29(1):45–62.