ABSTRACT

Many universities have had centers for entrepreneurship and other programs to stimulate an entrepreneurial culture and provide knowledge about effective entrepreneurship. The National Academy of Engineering and others have pointed out that the engineer of the 21st century needs to be entrepreneurial. This paper considers whether entrepreneurship can be learned and the specific skills and traits that are associated with successful entrepreneurship. It examines the activities of entrepreneurship centers and other programs for engineering students and concludes that there are a lot of resources available to develop an entrepreneurial mindset. The problems are that we need to reach far more students, continually learn more about what works to make them effective entrepreneurs and innovators and develop more champions within the engineering faculties to get our students what they will need.

The importance of entrepreneurial thinking for engineers

The National Academy of Engineering has pointed out that engineers will need to be much more entrepreneurial in the 21st Century. Engineers should be the most innovative professionals, and that means more than discovering new knowledge and solving technical problems. Innovation means commercialization, as well as invention, and that requires at least some passion to see new technology implemented and at least some knowledge of what implementation generally requires. While it is true that engineers have been the source of innovations that added much to the quality of lives all over the world, the difference now is that an entrepreneurial mindset is essential for almost all engineers, not just the few who start their own companies. Rapidly changing technologies and market demands mean that there is seldom time to get a good set of requirements that will be unchanging for the design process. Design increasingly includes the voice of the customer, financial considerations and production and supply chain issues. The role of the engineer in the cross functional teams that do new product and process development is greatly facilitated when that engineer understands the overall picture from idea conception to an adequate number of satisfied customers.

There are also other practical incentives for the engineer’s bag of tools to include entrepreneurial skills. Employment in Fortune 500 companies has been going down for decades, and engineers are increasingly finding themselves in small and medium sized enterprises. Most new jobs have been occurring in small and medium sized companies, especially those that are young and growing rapidly – i.e. entrepreneurial companies. Even if graduates are still in high demand by large firms for the beginning of their careers, they are likely to be moving to a much more entrepreneurial environment later. Career management now means far more than the very real challenges of staying up to date technically. Technical professionals need to be able to evaluate the business prospects of the firms to which they attach their futures, and that means they need to assess the potential of the prospective employer in the marketplace. Besides, solving
Can entrepreneurship be learned?

Since the audience for this paper is made up those interested in the ASEE Entrepreneurship section, the notion that engineers should know about entrepreneurship probably does not require a great deal of support here. It is worth noting that there is not universal agreement that higher education can teach people to be entrepreneurs. For example, David Birch, one of the pioneers on entrepreneurship scholarship who first noted its importance to job creation and coined the expression “gazelles”, was quoted in a 2004 interview saying that he did “not think that it could be learned in a classroom”. He also said that business schools did not teach the three needed skills of “selling, managing people and creating a new product or service”. However, even Birch says that entrepreneurship can be learned by apprenticeship. While he saw the essential skills as hard to “codify and put into a curriculum”, he said that entrepreneurship could be learned through the experiences of apprenticeships.

Judith Cone, Vice President of Kauffman Foundation has a different point of view, and her organization along with the Coleman, Kern and other foundations have invested millions to assist in entrepreneurship education, as have a number of government entities. Cone points out that universities are focal points of learning communities that form the foundations of entrepreneurship, especially with respect to technology. She also cited Peter Drucker’s observation in the 1980’s that there was a need for more knowledge to do entrepreneurship and that it was time to develop the “principles, the practice and the discipline.”

Economists view the supply of entrepreneurship as subject to the same forces as other resource behavior. That is, it depends upon the perceived benefits and opportunity costs of the decision to pursue the entrepreneurial path. For example, the explosion of entrepreneurship in India and China can be traced to expanded awareness and lowering of obstacles to initiating new enterprises. The first step toward applying this is to note that for engineers to become entrepreneurial, they need to be aware of its benefits and have a realistic view of the risks and the costs of pursuing the path of change, rather than acceptance of the status quo. This supports the assertion that the education of engineers should include entrepreneurship, but it does not answer the question about how this can be done.

Getting entrepreneurial thinking to be part of the preparation for the engineering profession is an innovation. The best way to get innovations adopted is to have the market pull them into widespread use. The development of demand follows the generally accepted 4 steps of
Awareness  
Persuasion  
Decision  
Confirmation

There are lots of ways to make people aware. Persuasion in environments of an overload of various messages about their futures is a bigger problem. In the context of getting engineering graduates to exhibit entrepreneurial behavior, the decision stage means that they commit the time and work needed to acquire the needed concepts, change underlying assumptions and attitudes and take actions such as starting their own innovative ventures, seeking employment with start-up and other innovative firms or at least showing a passion for using their knowledge to bring about positive changes. Confirmation refers to both the consistency of the entrepreneurial behaviors over time and the spread of the entrepreneurial mindset to more and more engineers.

The actual impacts of activities to promote entrepreneurship need to be subjected to assessment metrics. Of course, participation alone is not likely to indicate whether engineering graduates are likely to be effective entrepreneurs either in starting their own ventures or being change agents (or intrapreneurs) in existing organizations. This requires that we go deeper into the attributes that are acquired in professional preparation. Most of the work on more rigorously measuring outcomes seems to be on the course level, rather than overall programs or centers. For example, Okudan, Kisenwether and Rzaza have reported on the assessment of the courses in the entrepreneurship minor at Penn State. Using faculty input and a review of entrepreneurship education in the literature, they identified the following knowledge and skills for improvement of entrepreneurial potential.

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<th>Risk Taking</th>
<th>Need for Achievement</th>
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<td>Leadership</td>
<td>Creativity</td>
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<td>Customer Orientation</td>
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Work is progressing on instruments to measure these aspects of knowledge, skills and traits that might be affected by entrepreneurship centers and programs, but there are at least two issues to consider about them. First, it should be noted that most of this list is not unique to entrepreneurship education efforts. Most of these characteristics can be developed in other courses, including or perhaps especially engineering courses. Entrepreneurship is a great vehicle for teaching these things, but it is not the only way. Integrating teamwork and communication, for example, should be done across the curriculum. Second, there should be caution about the empirical basis and definition of the attributes. While this list is well supported by decades of literature by business educators, and engineers and entrepreneurs are quick to agree with them. However, the
correlation of at least two of them with entrepreneurial success may not be what it seems to conventional wisdom.

Risk has long been associated with entrepreneurship. Frank Knight, a prominent early 20th century economist defined entrepreneurship in terms of the rewards for bearing risk and uncertainty. However, Joseph Schumpeter, a contemporary of Knight who is even more famous for the intellectual foundations of entrepreneurship, differentiated the entrepreneur or innovator from the capitalists who risked their money. Schumpeter went so far as to say that

“the entrepreneur is never the risk bearer …. The one who gives the credit comes to grief if the undertaking fails.” And “Risk-taking is no case an element of the entrepreneurial function.” (p.137)

Of course technology entrepreneurs often function as capitalists, especially with their own “sweat equity,” and Schumpeter acknowledged that the entrepreneur risked his reputation, which is probably the engineer’s most important asset. However, it has never been clear that entrepreneurs were wild-eyed, risk loving mavericks, and it certainly does not fit the technology entrepreneurs and innovators of the 21st century. As Marc Dollinger of Indiana University has said

“What is emerging today is a class of professional entrepreneurs who rely more upon their brains than their guts – and who have been trained to use both methods and technology to analyze the business environment”. (p. 9)

Understanding the proper place for risk taking in preparing entrepreneurial engineers requires some more rigorous consideration of risk and uncertainty. Risk is the variability of outcomes that can often be measured, or at least be subject to subjective probability. Uncertainty refers to the confidence one has in anticipating what is going to happen. For example, the forecast for rain for tomorrow and next week may be 10% for both days, but the forecast for next week is a lot more uncertain.

Successful technology entrepreneurs need to tolerate uncertainty or ambiguity because newness assures a lack of data to estimate risk. However, they are not risk lovers. In fact, many of the best entrepreneurs are risk neutral or even risk averse. How many of them like to gamble in casinos or play the lottery for example? Successful technology entrepreneurs are risk managers. They take risks because they are justified by their perception of the expected returns from the actions, and they do what they can to reduce the probabilities of undesirable outcomes. Few investors are looking to provide funds to river boat gambler types, and entrepreneurship education efforts should be focusing on developing responsible risk managers who will be effective at implementing innovation.

Another attribute where caution should be applied is creativity. Drucker said that

“. bright ideas are the riskiest and least successful source of innovative opportunities. The casualty rate is enormous. No more than one out of a hundred patents for an innovation of this kind earns enough to pay back development costs and patent fees. A far smaller proportion, perhaps one in five hundred, makes any money above its out of pocket costs.” (p. 130)
Drucker emphasizes looking for opportunities in unexpected changes, incongruous situations, and alterations of industry structure, perceptions and demographics. That is, the innovations with more likelihood of success are those for which there is current market demand, rather than a bright idea that is not understood. It should also be stressed that a really creative idea well protected by intellectual property provisions is still a long way from market success. Increasingly, the evidence says that the idea requires consistently effective execution of good business decisions. This is a significant part of the explanation for why it is so hard to get university discoveries commercialized.\textsuperscript{11} This implies that we need to be careful about the emphasis placed upon creativity as part of the preparation for entrepreneurship. This is not to say that developing creativity skills is not important for entrepreneurs and engineers, but that it should not be the primary focus.

The overall conclusion on learning and entrepreneurship is that it is like a lot of what is done in education. Entrepreneurship education is no more likely to produce another Bill Gates or Steve Jobs than the best music schools can create another Mozart. However, entrepreneurship courses and other activities can increase awareness of the opportunities and provide knowledge on what it takes to increase the chances for success in innovation. Like other education, we need to look at works best in doing this. It appears that experiential education is embraced as a most powerful way to instill entrepreneurial attributes and even Birch, the critic cited above, said learning could occur in apprenticeships, but projects and internships are not the only ways. Moreover, the experiential approaches can be costly.

**Background on entrepreneurship centers**

According to the Kauffman Foundation, about two thirds of the colleges and universities in the United States have at least one course in entrepreneurship.\textsuperscript{4} Many campuses have entrepreneurship centers with extensive on-campus courses and activities and substantial outreach to their communities and beyond. While a later section will focus on some specific programs for engineers, it is instructive to examine the entrepreneurship centers to ascertain what universities are doing to prepare technical graduates that are ready to be effective innovators.

Entrepreneurship centers were being established at universities over three decades ago and the number of them continues to grow. The Global Consortium of Entrepreneurship Centers has well over a hundred American institutions in its membership, and almost half of them have engineering programs. There are also other centers involved with engineering students that are apparently not members. Most of these entrepreneurship centers are in business schools and much of their attention is on serving business school students. However, even in their early days a number saw the advantages of involving schools of engineering. For example, the Center for Entrepreneurship at the University of Colorado at Boulder was a joint venture of the business and engineering schools and there have been lots of other examples of formal and informal cross-campus collaboration.\textsuperscript{12}
Activities and impacts of entrepreneurship centers

In an effort to discover the specific ways the centers for entrepreneurship might be impacting engineering students, this writer examined the center websites for over 75 institutions that have engineering curricula. Discussions at conferences, visits, phone calls and email exchanges provided supplementary information on over 25 of the centers. This examination was supplemented by a very simple email survey sent to 71 directors and/or known contacts involved in engineering and entrepreneurship. Attendees at the Stanford University Roundtable on Entrepreneurship Education and the annual meetings of the National Collegiate Inventors and Innovators Alliance provided most of the contacts. Twenty-one of the contacts provided emails to answer the survey questions below after two requests were made. (The list of respondents is at the end of the paper). These responses and the more informal discussions that preceded the survey and are continuing indicate that there is a wide range of interesting activities to promote entrepreneurship at many schools. In fact the range is wide enough that drawing precise inferences from such a heterogeneous sample of a small size may be premature. However, the data and its collection are adequate for some qualitative conclusions in which there can be confidence.

Questions for email survey

1. What statement best describes the way your entrepreneurship center was established?

24% A gift or potential gift caused school administrators to organize an effort to establish the center.

29% A multidisciplinary group saw the need and initiated a plan and sought resources to establish the center.

38% One or a few faculty members pushed for the establishment of a center.

29% We do not have an entrepreneurship center.

Some respondents provided more than one answer to these questions. For example, a major gift may have launched a center, but a champion or group of champions had been making the case for action. It is also interesting to note that several people with interests in entrepreneurship for engineers did not have centers at their campus.

2. What statement best describes the relationship of your center to engineering education on your campus?

33% Engineers are a major focus of our center’s activities.

38% Our center welcomes engineering students in the same way as other students
5% Our center is focused on the needs of the business school and its students

Our center’s focus is primarily on scholarship

5% Our center has had little or no contact with engineering faculty or students

While a third of the respondents said engineers were a major focus, it should be noted that most of these were from schools with very substantial percentages of engineering majors in their student bodies. However, it should also be said that there is a desire to reach out to other disciplines, even by centers that are housed in business schools. Conversations have revealed that many involved in entrepreneurship programs and centers find the disciplinary silos of even primarily technical universities make a lot of these efforts difficult.

3. What types of activities are carried out by your entrepreneurship center?

67% Lectures

52% Certificate programs

61% Business plan contests

71% Support of entrepreneurship club activities

67% Mentors

62% Workshops

48% Research on technology based entrepreneurship

29% Assistance to university tech transfer programs

38% Support of start-up businesses

Other – please describe briefly below

There were two respondents who noted that they also conduct forums to showcase potential start ups as another important activity. Another has students invest venture funds. Few of the institutions are able to pursue all of these, and it is clear that they all take considerable effort and resources. Finding adequate support for these endeavors appears to be a general problem.
4. What metrics are used to account for the effectiveness of the center?

- **61%** Number of students exposed to entrepreneurship
- **33%** Number of student or faculty/staff companies that are launched
- **52%** Attendance at events
- **57%** Enrollment in certificate programs and/or courses on entrepreneurship
- **29%** Student surveys of satisfaction and/or behavior changes
- **19%** Alumni surveys of satisfaction and/or behavior
- **24%** Employment of students in entrepreneurial companies
- **10%** Employer surveys
- Other metrics – please describe

The “Other metrics” included such things as research money raised, profits generated for the university and the number of companies receiving external funding. While these metrics indicate that there is some emphasis on using entrepreneurship centers to generate the economic benefits of entrepreneurial ventures, most of the metrics seem aimed at student engagement and satisfaction with the programs. While everyone agrees that longitudinal data after graduation may be more important to assess actual impacts, such data is not easy to collect. In addition to the usual barriers to successful surveys, there is a reluctance of alumni offices to bother potential benefactors more than necessary.

Some, including both some donors and some public officials, view entrepreneurship centers primarily in relation to the number of new firms created. While launching companies generates excitement and publicity and sometimes even financial returns, it is not appropriate to put too much emphasis on this measure. Earlier discussions have suggested that the goals of entrepreneurship for education of engineers should be much broader because all engineers can benefit from a more entrepreneurial mindset. Moreover, as indicated above, getting reliable data on the impacts of programs after graduation is very difficult. Even the most aggressive programs are unlikely to see more than a few per cent of participating students actually starting companies and those that do so even shortly after graduation are not particularly motivated to report back to their institutions. At the same time, there is an argument that assessment of outcomes should improve. The field of entrepreneurship education is now mature enough for us to generate better information about the long term benefits of student experiences.
5. What percentage of engineering students would you estimate have been affected by the entrepreneurship center or other entrepreneurship activities of your institution?

- 43% Less than 5%
- 33% 5 – 25%
- 19% 25-50%
- _______ 50% +

These responses show that centers and programs are not reaching a majority of the engineering students. While there are some centers that make engineers a major focus and some have special courses and programs that directly involve them, there is not much emphasis on reaching a broad range of the engineers. This is especially true at universities where entrepreneurship is in the business school, and engineers are viewed as just another target of their outreach. If engineering educators want students more involved in the activities offered, it appears that some encouragement must be generated within the engineering programs. Indeed, those schools that have special efforts to involve engineers seem to have one or more champions among the engineering faculty.

The list of activities above certainly shows that there are significant resources available at campuses for the entrepreneurship education of engineering students. Some of them, like joint courses with projects and involvement of multidisciplinary business and technical teams in assessing university intellectual property’s commercial potential have the ability to provide the awareness, understanding of concepts and experience that can prepare students to be entrepreneurs. However, participation by engineering students generally requires initiative on their part, at least some flexibility in their curriculum and schedules and perhaps some coaching from engineering faculty.

There is at least some evidence that employers appreciate the traits of students who have had entrepreneurial education, but not very many centers are using surveys of employers.

The bad news on the effectiveness of centers in preparing entrepreneurial engineers is that most respondents estimated that they were affecting less than 25% of the engineering students, and only a few claimed they were reaching over 25%. There clearly needs to be more action to get the breadth of entrepreneurship education that will be needed by our students and our economies in the years ahead.

Programs for engineering students

There are schools with entrepreneurial programs that do not have centers and particular programs at some centers that are worthy of special note. Valparaiso University does not have a center but they are one of several schools that are in the Kern Engineering and Entrepreneurship Network (KEEN). While there is no center, there is a team of business
and engineering faculty that are pursuing a number of activities to increase the entrepreneurial mindset of the engineering students and others on the campus. This KEEN initiative which is focused in the Midwest and involves a number of smaller schools should soon be producing a lot more information on effective approaches for reaching engineering undergraduates. There are also schools that have additional programs, some of which are within the engineering schools. The Stanford Technology Ventures Program is an example of one that serves educators generally as well as its own campus, even though there is also a center for entrepreneurship in the Stanford Business School. Rensselaer has a Vice-Provost for Entrepreneurship and a wide range of programs to make the whole institution an entrepreneurial environment. Olin College of Engineering has integrated entrepreneurship into their education of engineers and uses the impressive resources of Babson College to supplement its own. A number of schools involve their students in incubators both with their own companies and in work opportunities with start-ups. Internships for engineering students in entrepreneurial companies have been used for over a decade, and Rose-Hulman Institute of Technology has been providing them through on employment at Rose-Hulman Ventures. There are also new master’s degrees in entrepreneurship and certificate programs in entrepreneurship for graduate students in technical fields that will provide a place to go for graduating B.S. engineers who are serious about commercializing their ideas.

Conclusions

The evidence seems clear that familiarity with the opportunities and basic principles of entrepreneurship is going to be needed by 21st century engineers. There is also adequate support for the assertion that much of what they need to learn can be acquired as part of their higher education, especially if there is an experiential component. The centers for entrepreneurship represent impressive potential sources of activities for students, and there are many other innovative programs. However, there is a lot more to be done. Specifically, the activities need to involve many more of the engineering students, and we need more and better understanding of what works to produce the 21st century technology entrepreneur that we desperately need. This means that more engineering educators need to step up to the role of champion for the entrepreneurship education of our students.

References
1. National Academy of Engineering. Engineer in 2020

**SCHOOLS IN THE SURVEY**

Berkeley University  
University of California at Santa Barbara  
University of Central Florida  
Duke University  
Florida International University  
University of Florida  
Georgia Tech  
Johns Hopkins  
Illinois Institute of Technology  
University of Iowa  
Lawrence Technological University  
Michigan  
Penn State  
Purdue  
Rensselaer Polytechnic  
Rose-Hulman Institute of Technology  
Rowan  
Smith  
Valparaiso University  
Carnegie Mellon University  
Rice University