Launching an Undergraduate Engineering Entrepreneurship Program

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Abstract
Historically, entrepreneurship education has been based in business schools, particularly at the MBA and graduate school level. However, with advances in technology driving new products and companies, engineers are becoming key players in new ventures. Thus, there is need for training students at the undergraduate level to manage, lead, and innovate our technological future.

With the support of a grant from the GE Learning Excellence Fund, the College of Engineering through the Problem-Based Learning in Entrepreneurship (PBLE) Program is developing engineering undergraduate courses that incorporate product conceptualization, design, feasibility (technical and market) in a collaborative, interdisciplinary setting. The PBLE Program targets students from three academic areas: Engineering, Business and IST (Information Sciences and Technology). This paper explains the processes used to define the new entrepreneurship curriculum, core courses, assessment approach, institutionalization of engineering entrepreneurship, and lessons learned.

Introduction
Over the past three years, five factors combined to demonstrate a need and interest in a problem-based, collaborative learning program (and Minor) in entrepreneurship for Penn State undergraduate engineering students.

- Research data is confirming that active, collaborative learning methods produce statistically significant gains in student learning than those associated with more traditional instruction methods.\(^1\)
- Design courses provided continuously throughout the undergraduate education process is a goal outlined in the ABET2000 Engineering Criteria.\(^2\)
- Most recent feedback from the Industrial and Professional Advisory Committee (IPAC) for Penn State’s suggests continued focus on written and oral communications, ability to work on multi-disciplinary teams, project planning and management skills.
- Alumni interest and financial support via endowments for engineering entrepreneurship education is growing.
- Participation in REEE2000 and REEE2001 Conferences – Roundtable for Engineering Entrepreneurship Education, at Stanford University - confirmed that good engineering design in inherently a creative process, and gaining business acumen is key for engineering entrepreneurship education.
Literature on the psychology of entrepreneurs shows a variety of theories. Some researchers see entrepreneurial behavior or personality as more dynamic and are an interplay of environment (situation), personality traits, perceptions, values, beliefs, and background. \cite{Kreuger and Brazeal, 1994}, with the definition of entrepreneurship as “the pursuit of an opportunity irrespective of existing processes.” Schein \cite{1994} asserts that the desire for autonomy, not simply having it, is a key for an entrepreneur. True entrepreneurs, according to Schein, initiate ventures for creative rather than economic reasons. Using these theories, Penn State’s PBLE program: provide an environment fostering creativity, innovation, risk-taking, and leadership in active-learning curriculum, so that undergraduate students’ outlooks on work and employment can be viewed as entrepreneurial. Therefore, entrepreneurship is defined as creating something of value from an idea, and building in long-term value for the product or company with personal vision, passion, risk-taking, and creativity.

**Designing the Entrepreneurship Curriculum**

In December 2000, Penn State was awarded a GE Learning Excellence Fund grant for the Problem-Based Learning in Entrepreneurship (PBLE) Program. The two-year grant stipulated the following:

- All courses in the PBLE Program are to be collaborative, problem-based learning.
- The PBLE Program is to be developed and delivered in co-operation with the Smeal College of Business Administration and Penn State Altoona’s existing Entrepreneurship Program, which is an option in its B.S. in Business Administration Major.
- Assessment of student knowledge and skills

Several steps were made early to ensure the PBLE program would fit into the existing undergraduate programs in the three stake-holding colleges (Engineering, Business and Penn State-Altoona). This was a critical step. Unless the PBLE Program had buy-in from the three colleges, getting faculty to enthusiastically and willing teach the courses would be difficult.

First, the Dean of the Smeal College of Business Administration as well as Associate Deans and business teaching faculty helped outline the PBLE goals and problem-based, collaborative focus of the courses.

Second, the lead faculty member of the Entrepreneurship Program at Penn State Altoona (Dr. Tom Boyle) guided decisions on what courses to re-use at Penn State-University Park.

Third, all existing engineering faculty with any entrepreneurship interests were fully informed about the new engineering entrepreneurship program. Again, buy-in and understanding of the PBLE Program from engineering faculty was critical. Most engineering faculty, especially on tenure track, are reluctant to get involved in the non-technical, “softer” skill areas of engineering education in the 11 criteria, number 3 of ABET EC2000.\footnote{Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition Copyright © 2002, American Society for Engineering Education}
Fourth, Directors of existing Engineering Leadership Development Minor and Product Realization Minor were involved in early planning meetings to solicit their inputs, suggestions and feedback to the PBLE Program curriculum.

Core Courses
By May 2001, the courses and curriculum focus for the PBLE Program was defined. The PBLE Program (and proposed Minor) is composed of a 12-credit (four course) “core”. There are different core course lists for engineering, business and IST students. This approach ensures the needed “cross skills” needed for successful teams of engineering, business and IST students. New courses are in italics.

Engineering students:
- ENGR497D  Entrepreneurial Leadership
- ENGR497G  Entrepreneurship Business Basics
- ENGR407  Technology-Based Entrepreneurship
- ENTR430  Entrepreneurship and New Product Development

Business students:
- ENGR497D  Entrepreneurial Leadership
- QMM492  Introduction to Engineering Design Principles
- ENGR407  Technology-Based Entrepreneurship
- ENTR430  Entrepreneurship and New Product Development

IST students:
- ENGR497D  Entrepreneurial Leadership
- ENGR497G  Entrepreneurship Business Basics or QMM492 Intro. to Engineering Design Principles
- ENGR407  Technology-Based Entrepreneurship
- ENTR430  Entrepreneurship and New Product Development

Figure 1 summarizes the core courses, with preferred order of course from bottom to top.
Figure 1 – Engineering Entrepreneurship Core Courses provide “cross-training” for students, leadership, creativity, risk-taking and intrapreneurship exposure.

Students selected the remaining 6 supporting credits for the Engineering Entrepreneurship Minor from a list of over 30 courses. For example, engineering students can take additional business courses, and business and IST students can take more engineering “basics” courses. Students can double-count some technical electives, social/behavioral courses, or “out-of-major” credits, within the maximum amount allowed by their degree-granting departments.

Enrollment numbers (Table 1) for Fall 2001 and Spring 2002 show the immediate interest in the entrepreneurship courses.

Table 1: Enrollment summary for Engineering E-Ship Core Courses for Program Launch

<table>
<thead>
<tr>
<th>Course title</th>
<th>Fall 2001 enrollment</th>
<th>Spring 2002 enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Ship Business Basics</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Entrepreneurial Leadership</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Technology-based Entrepreneurship</td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td>Introduction to Eng. Design Principles</td>
<td>15</td>
<td>*</td>
</tr>
<tr>
<td>First-Year Seminar: Engineering E-Ship</td>
<td>20</td>
<td>*</td>
</tr>
<tr>
<td>E-Ship and New Product Development</td>
<td>*</td>
<td>20</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>117</strong></td>
<td><strong>142</strong></td>
</tr>
</tbody>
</table>

* Course not offered this semester
† Technology-based Entrepreneurship is a common course across three College of Engineering Minors, including the E-Ship Minor.
The PBLE Program and proposed Minor is currently structured for up to 80 students to be fully enrolled in the Minor. Assuming some funding increases, the goal is to have roughly 600 students per year taking at least one of the E-Ship courses, and the enrollment in the Minor could grow to over 100 students. With total undergraduate enrollment in the Colleges of Business, Engineering and School of IST to be approximately 12,000 students, the Engineering Entrepreneurship courses would be included in 5% of the student population’s curriculum from these academic units.

Assessment Approach
The assessment team provided early input on mapping of entrepreneurship course objectives to entrepreneurship skills. Table 2 summarizes the mapping of desired outcomes (changes in attitudes) to core courses.

Table 2: An Outcomes-to-Course Matrix for the four core PBLE courses helped map desired skills to course content.

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<tr>
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<tbody>
<tr>
<td>Risk Taking</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Motivation/Need for Achievement</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Leadership</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Innovation</td>
<td>x</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Customer Orientation</td>
<td>X</td>
<td></td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>Communication Skills</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Teamwork</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Develop Bus. Plans</td>
<td>x</td>
<td>(Portions of Bus. Plan)</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>Business Skills</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: **Bold** = outcomes/desired skills listed in PBLE proposal  
*Italics* = additional desired skills for students  
Capital **X** = strong course emphasis in the skill area

The need for a solid assessment approach was also an early design-driver for the PBLE Program, with several approaches in use.

*On-Line self-assessment using validated instruments*

The General Enterprising Tendency (GET) Test was identified the validated assessment tool for measuring trends and changes in students’ views of the following attributes: risk-taking, motivation/need for achievement, innovation/creativity, leadership, and entrepreneurial self-efficacy. Students take the on-line survey at the start of the first e-ship course in the program (and proposed Minor) and after their last E-SHIP course (or when they complete the Minor). The time span between the “entry” and “exit” survey will typically be over 18 months. A group of students taking none of the Engineering Entrepreneurship courses will be responding to the on-line survey at the same time as participating students to serve as a control group.

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Per-course evaluation of skills/knowledge
For the five undergraduate courses in entrepreneurship in the PBLE Program, the student’s grade is based in part on his/her teamwork and communication (written and oral) in the problem-based activities. Each E-Ship courses also included a content-based “pre-” and “post-” low-stakes test to assess entry knowledge for course content and the way this knowledge changes as a result of the course experience.

Business Plan evaluations
In ENGR497D, ENGR407 and ENTR430, completion of a business plan for a new product is required in the course. (In ENGR497G – Business Basics – a detailed marketing plan is one of the final course deliverables.) Using the rubrics, expert judges will evaluate the quality of the students’ business plans on several key dimensions. We will analyze the quality of the students’ business plans relative to their tenure in the PBLE program. It is our hope and expectation that the overall quality of the business plans created by the more experienced students in the PBLE program will be superior to the overall quality of the business plans created by the less experienced students in the PBLE program.

E-ship Competition with Judge’s feedback/scoring
An Entrepreneurship Competition is held at the end of each semester, with teams from the entrepreneurship classes presenting their new product concepts and prototypes to a panel judges who are were either technology entrepreneurs, or a venture capital investors. Each judge completes a one-page scoring sheet on each team. The judge’s scores and comments are used several ways:

- Feedback to the teams as guidance on what was well done and areas for improvement
- Likert scale data – to measure trends in quality of the product presentations across time
- Feedback to the faculty on what are the strong and weak areas of the student teams’ work from an entrepreneur’s or venture capital investor’s perspective

In summary, assessment in the PBLE program is a mix of student self-assessment and faculty/entrepreneur evaluation of outcomes, in terms of enhanced knowledge and mastery of skills.

Institutionalization and Dissemination
In Fall 2001, all the paperwork and faculty reviews took place for the approval of the Engineering Entrepreneurship Minor in the College of Engineering. The approval process is proceeding on schedule as of March 2002, with full Faculty Senate and Board of Trustees approval expected before May 2002. Information about the PBLE Program and the proposed Minor is disseminated through several channels:

- Website – created with pages for students, faculty, entrepreneurs, and industry. 
  http://e-ship.ecsel.psu.edu
- Membership in Technology Entrepreneur’s Roundtable in the CBICC (Chamber of Business and Industry of Centre County). Roundtable members are local technology
start-ups and small companies. Goal is to attract entrepreneurs into the classrooms as presenters, project mentors, competition judges and potential teaching faculty.

- Involvement in TCCP (Technology Council of Central Pennsylvania). TCCP includes technology companies in eastern and central Pennsylvania, plus venture capital firms, angel networks and business development offices.

Lessons Learned
Launching an engineering Entrepreneurship program (and new Minor) is an entrepreneurial event in itself. There are strong opponents as well as advocates, strictly budgeted resources, a tight timeline to show progress, the consumers (students) hard to reach due to college boundaries, and an unknown financial future. All of the stakeholders at the start of the engineering entrepreneurship courses and activities are creating something of value from an idea, and building in long-term value with personal vision, passion, risk-taking, and creativity. Below are five additional suggestions from lessons learned.

1. Build information bridges, from the start, to other colleges involved in or impacted by an engineering entrepreneurship program (and new Minor). Support for an engineering entrepreneurship program at the Dean level is obviously critical. However, support and knowledge about the Engineering Entrepreneurship Program at the faculty, staff and advising levels in all of the colleges are also critical.

2. Maintain these information bridges to other colleges. Get the ENGR-designated entrepreneurship courses cross-listed with other colleges as soon as possible is important. Presentations and “info packets” must be provided to undergraduate advisors in the other colleges and all Engineering Departments. The advisors are a key link to perspective entrepreneurship students; working with them, and recognizing their support and help.

3. Get seasoned technology entrepreneurs into the classrooms as part-time faculty. The PBLE program is successfully using a co-teaching model, where the entrepreneur is paired with an engineering faculty member. This provides win-win scenarios for everyone involved – the entrepreneur (learning the teaching “ropes”), the faculty member (learning of real-world entrepreneurship challenges), and students (exposure to a person who has lived and breathed entrepreneurship as well as experienced faculty.)

4. Network with the local technology companies, and arrange for entrepreneurship students to get work experience in whatever mix of credit and pay can be arranged. Students must experience the entrepreneurial work environment to fully understand what is involved.

5. Funding, funding, funding. From the start, work with the development departments in the colleges to spread word about the new engineering/technology entrepreneurship program (or Minor). Write a solid vision and mission statement and publicize it well to perspective “investors” or supports of the program. Also, look for emerging entrepreneurship funding at the state and national levels.

Conclusion
The Entrepreneurship Minor has been successfully launched. All Spring 2002 semester engineering entrepreneurship classes are filled, with waiting lists of students. In the Fall 2002 semester, course offering will be increased to meet expected demand. The future goals (like with every entrepreneurial endeavor) are to learn fast from the failures, clarify the vision, innovate the courses and classes, solidify the financial base, and expand as resources allow.
Bibliography


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Professor of Environmental Engineering at Penn State University. Dr. Matson holds seven patents, and is author of several books on expert witnessing and engineering innovation. His primary research interests are industrial emissions, pollution prevention, sustainability, environmental process design, entrepreneurship, creativity, and innovation. He developed and teaches ENGR407 Technology Based Entrepreneurship, as well as teaches six other courses in the Civil and Environmental Engineering Department and the Science, Technology and Society (STS) Minor, and encourages student-entrepreneurs to risk failure, and to unlearn years of practicing risk aversion.