Dartmouth's Ph.D. Innovation Program

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Abstract – Dartmouth's Ph.D. Innovation Program is described. The rationale and structure of the four-year old program is discussed. Significant success in its objectives to contribute to the Nation's technological and economic leadership has already been achieved by the program despite its youth and small size.

Keywords: Innovation, Enterprise, Entrepreneur, Ph.D., Dartmouth

INTRODUCTION

In 2005, "Innovate America", a report from the National Innovation Summit, was released by the Council on Competitiveness [1]. This report, authored by individuals drawn from the corporate world, academia, and government, argued that for the US to maintain technological and economic leadership, a substantial investment in the development of a technically competent workforce was required. As the report articulates, nations that are able to provide conditions favorable to innovation and entrepreneurship, including a strong technically-trained workforce, stable government, culture that accepts and rewards risk taking, and the availability of early stage capital are those most likely to claim positions of leadership in the 21st century. While this report and others appearing at that time [2, 3] described the need for developing more engineering talent within the U.S., and an overall need for changes in engineering education to incorporate more open-ended problem-based learning and foster skills needed for innovation and entrepreneurship, their emphasis was generally on undergraduate science and engineering education. Discussion of graduate programs focused primarily on the need for increased research and fellowship funding to encourage greater numbers of domestic students to pursue advanced degrees in engineering and science.

Engineering Ph.D. programs focus, appropriately, on helping students develop the skills needed to conduct original research. Their structure, emphasizing advanced coursework and publishable research, differs little from Ph.D. programs in the sciences. Similarly, some might argue that for many programs, "success" can be defined as placing top doctoral students in academic positions at peer institutions. While this is one important outcome for Ph.D. engineering students, we estimate, based on the number of engineering assistant professors in the United States and the number of Ph.D. degrees granted in engineering each year, that no more than approximately 10-15% of graduates obtain tenure track faculty positions [4, 5]. Most engineering Ph.D. recipients pursue careers in industry, often in industrial R&D, where their deep technical knowledge is of immediate application. In both of these paths, however, the educational program focuses entirely on the students' technical education. Little attention is paid to the potential benefits associated with helping engineering Ph.D. students develop, as part of their Ph.D. program, the business and organizational skills needed for technology entrepreneurship. Programs designed to help students explore commercialization of their research, often in collaboration with business schools, do exist at many universities, but there are not many programs that focus on helping Ph.D. students develop the knowledge and understanding necessary for technology entrepreneurship as a core part of their Ph.D. education.

To address this, in 2007-2008 the faculty of the Thayer School of Engineering at Dartmouth College developed a specific "Innovation Program" with the objective of providing a much more structured approach to developing the skills needed to be a Ph.D.-level technology entrepreneur. The program was structured with the goals of providing introductory exposure to the relevant business curricula, providing practical experience through a mandatory internship in a startup company late in a student's Ph.D. program, providing intensive mentorship from successful

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entrepreneurs and venture capitalists, and building an understanding of the process of turning complex research into innovative technology. The program is designed to teach them to recognize the skills needed to bring about successful innovation and associated new enterprise, and to provide the opportunity to take risks, possibly fail, and ultimately learn from the experience in a structured environment.

PROGRAM STRUCTURE

Structure

The Ph.D. Innovation shares a common core with Thayer's Ph.D. program, which is comprised of applied math and engineering coursework, a multi-year research project, professional skill-building, an oral qualifying examination and a Ph.D. thesis defense. The program adds Tuck School of Business (adjoining the Engineering school on the Dartmouth campus) and Thayer Innovation coursework and an internship, preferably in a startup, which could be the student's own venture. Innovation program coursework includes corporate finance, a course in law, technology, and entrepreneurship, an elective such as accounting, and Thayer School's unique Introduction to Innovation course. The Introduction to Innovation course was specially designed for the program and provides instruction and practice in commercialization of new technologies over a nine-month period. Thayer is able to deliver a rich experience in this regard due to a long history of integrating the practical aspects of market analysis and business planning into interdisciplinary engineering design project coursework at the undergraduate level. Students serve as teaching assistants for our undergraduate engineering design project course while advancing their own ideas through the stages of development and commercial analysis covered in the course. Guest lectures are presented by visiting entrepreneurs, venture capitalists, and inventors. In the first three months students report on their project orally and in written form and are graded on a pass-fail basis. Students who pass this checkpoint spend the final three months of the Innovation Course period developing a business plan and presenting it to a panel of experts for a grade.

Recruiting

A core requirement for students selected for our program is the same as the standard Ph.D. program - strong promise for academic success in coursework and research. The overlay emphasis on business and entrepreneurship coursework and activities must not come at the expense of rigor in advanced engineering sciences coursework and performance in the adviser's lab, whether on the adviser's or the student's own research. While the core requirements are the same, the challenge in recruiting is finding students who have characteristics and interests that go beyond the core. The way we look at this has changed in a subtle manner over the first few years of the program as students come into and successfully complete the program. Initially, the assumption was that a percentage of the Ph.D. candidate population either has a strong interest in entrepreneurship or a research idea they want to develop, and this type of student was the main target for the program. Our program is the only one of its kind and has been viewed by candidates as highly unique and exclusive. More recently, we have come to the realization that some of our own faculty entrepreneurs are what one might call "adventitious entrepreneurs" who did not necessarily pre-meditate an entrepreneurial role, and that perhaps this is the more common story for engineers with advanced degrees. Recognizing this, we are expanding the target and messaging beyond students ready for entrepreneurship or bent on commercialization to include those that are interested in preparing for this opportunity down the road and broaden their future options. This change supports what we always knew: that all engineers will benefit from additional training in business and entrepreneurship. To cast the net widely, we have employed both highly targeted tactics such as recruiting through alumni and faculty networks and from within our own pool of existing students, and broader tactics such as posters and Facebook ads to reach all Ph.D. prospects at targeted universities. We continue to refine these approaches in the early years of the program.

Admissions

Candidates submit the same core application materials as for the Engineering Ph.D. program, including GRE/TOEFL scores, intent essays, letters of recommendation, and transcripts. Additional materials required are a two-page essay elaborating on their interest in innovation and providing an example of creativity in arriving at a solution, a sample funding proposal for a technology development project, and a C.V. Applications are due at the same time as our regular Ph.D. program applications, and the screening process begins in a similar way, but is performed by a dedicated faculty panel focused on innovation requirements and fit. Students who are chosen for consideration are invited to a panel interview. The panel further confirms the interest and aptitudes of the candidate and provides the candidate an opportunity to demonstrate fundamental knowledge, critical thinking, and presentation skills around their technology interest area.

Financial Constructs

Ph.D. Innovation students are supported by graduate research assistantships for the first two years of the program, funded via adviser-secured grants or fellowships. In this period of the program, coursework and professional skill-building is emphasized as adviser-directed research ramps up. In the third year, research focus shifts from being adviser-directed to being candidate-directed, and fellowship funding is provided through Thayer School. In most cases, five full years of funding support the student through the acquisition of the Ph.D. in engineering, advance the adviser's research agenda, and support the student's innovation training and personal research agenda.

Assessment

Program assessment instruments include high-touch mechanisms such as meetings and check-ins with the Dean and the faculty director of the program, and the Assistant Dean for Student and Academic Affairs, and an annual meeting with at least one member of the school's Board of Overseers. In addition, standard annual Ph.D. program assessment surveys are conducted. Adjustments made to the program based on assessment feedback have been enhancing the community of participants and providing additional advising during internship planning. The success of the program is not presently measured on intellectual-property generated or enterprise-ventures formed, although these significant outcomes are noted; half of the students in the program have been named on IP disclosures thus far, approximately three times the baseline level for our Ph.D. program. As with all long-term investments, program success will need to be measured over a substantive time-scale.

Brief History Thus Far

The program began in July 2008 with a goal of admitting anywhere from zero to five students a year based on interest and match. As of Fall 2011, ten students have been or are currently engaged in the program. By June 2012 four students are expected to have gone through the program. Two of these have founded or co-founded startup companies in energy and life sciences sectors, and two have joined startups in energy and medical device sectors. Of the six students currently in the program, three men and three women, one is in the middle of completing an MD/Ph.D. joint degree program with Dartmouth Medical School and will continue to residency after completing the Ph.D. Innovation this year, and five others will graduate over the next several years. Internships have taken a variety of forms: the student's own venture in two cases, a later stage startup in one, and an early stage startup in another. Feedback from students is quite positive, and we continue to evolve the program and its features based on feedback.

Lessons Learned and Improvements

Perhaps one of the most important lessons learned in this program is that a modicum of education in the area of innovation and enterprise goes far in overcoming the natural barriers engineering personalities have with creating enterprises. In fact, it seems many engineers often find a lack of education in the areas of business a formidable psychological barrier to taking the leap to initiating a new enterprise. However, most Innovation Program Ph.D. students, well-equipped with mathematical and analytical skills, find that core entrepreneurial business concepts (e.g., legal, IP, accounting, business plans, etc.) are relatively easy to learn. In a phrase, learning entrepreneurial business mechanics is not rocket science. Of course, taking risk does not come easily to most engineers and we can only diminish the perceived risk through preparation.

Another lesson learned is that training students in this area, like in research, requires one-on-one mentorship and coaching. In a program that is a subset of fewer than 100 Engineering Ph.D. candidates school-wide, each student's background, needs and trajectories are rather different from one another. A one-program-fits-all approach does not work well and has been difficult to fashion. Instead, great flexibility is required to achieve the program objectives.

Like all faculty, Dartmouth's Engineering Faculty are diverse in their opinions about most subjects except perhaps for the need for quality education for undergraduate and graduates alike in Engineering. The Ph.D. Innovation program, while still in its youth as a program, has garnered a range of opinions from its faculty. While generally all supportive, faculty that are highly academic track without much exposure to industry are less convinced of the need for such a program compared to those that have had some exposure to the commercial world. Some of us believe that all our engineering students should have some minimum training in innovation and enterprise. This is because engineering has always been associated with the invention and application of new technology for society in both public and private sectors and often calls for the creation of new enterprises. It is therefore important to communicate continuously the need and importance of such innovation and enterprise training for some of today's Ph.D. students. This is an on-going process and our successful outcomes help cement the relevancy and importance of the program.

An area of improvement for Dartmouth is in creating a larger pool of well-qualified applicants to the program. Relative to most of its Ivy League and other peer institutions, Dartmouth is a modest-sized school, especially for graduate study, and the climate in northern New England is for those that relish strong seasonal variety. Thus, the pool of students that are cognizant of our program and apply to Dartmouth for graduate engineering study is growing but has not reached our targeted size. We need to better communicate our Ph.D. Innovation program to our feeder schools and develop new feed paths for our program.

CONCLUSIONS

Approaching its 4th birthday, the Ph.D. Innovation Program at Dartmouth's Thayer School of Engineering has already been able to measure significant successful outcomes from a relatively small group of Innovation Program Ph.D. students. We believe that such training in innovation and enterprise is an important step in sustaining and increasing technological and economic vibrancy in the U.S., and worldwide. While our program is young and continuously improving, we feel we are on the right path for leadership at the forefront of future engineering education.

REFERENCES

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[4] American Society for Engineering Education, "Profiles of Engineering and Engineering Technology Colleges," 2010 Edition, The American Society for Engineering Education, Washington DC, 2011. According to the 2010 "Profiles," in 2010 there were 8,628 doctoral degrees granted in engineering [this excludes computer engineering degrees granted outside of engineering]. The "Profiles" also indicate a total of 5,360 Assistant Professors of engineering in Fall 2010. Assuming an average 6-year tenure as Assistant Professor and a 1:1 replacement suggests 890 replacement openings each year if the number of assistant professors is approximately constant. These numbers, and recognition that there is ongoing growth in many engineering faculties as well as hiring at the more senior levels, led to the 10-15% estimate.

[5] National Science Foundation, National Center for Science and Engineering Statistics, "Science and Engineering Indicators: 2010," http://www.nsf.gov/statistics/seind10/start.htm, Appendix Table 2-28. Accessed January 27, 2012. Report indicates 8,066 doctoral degrees granted in the US in engineering in 2007, most recent year indicated.

Joseph J. Helble

Joseph J. Helble came to Dartmouth in 2005 as the 12th Dean of the Thayer School of Engineering and a Professor of Engineering. Prior to joining Dartmouth, Dr. Helble was the Roger Revelle Fellow of the American Association for the Advancement of Science (AAAS), spending a year addressing technology policy issues in the office of U.S. Senator Joseph Lieberman. He has also served as professor and chair of Chemical Engineering at the University of Connecticut, and from 1987 to 1995, was employed as a research scientist at Physical Sciences Inc. Dr. Helble is the author of over 100 scientific publications in the areas of air pollution, aerosols, and nanoscale ceramics, and 3 U.S. patents related to nanoscale ceramic powder production. He holds a B.S. from Lehigh University and a Ph.D. from MIT, both in chemical engineering.

Carolyn E. Fraser

Carolyn E. Fraser came to the Thayer School in November 2009 to the position of Assistant Dean for Academic and Student Affairs where she develops academic and student programs and has oversight for graduate studies administration and student life activities. Ms. Fraser enjoys developing entrepreneurship resources and networks for Thayer students and participating regularly on student project review boards. Prior to Thayer School, she held a variety of roles in industry, building extensive experience in healthcare and information technology in both the U.S. and Europe. Ms. Fraser holds a Dartmouth A.B. in Engineering Sciences and a Thayer School B.E. with a concentration in computer engineering.

Eric R. Fossum

Eric R. Fossum joined the Thayer School of Engineering at Dartmouth faculty in 2010 and is a Professor of Engineering and serves as faculty coordinator for the Dartmouth Ph.D. Innovation program. He is best known for the invention of the CMOS image sensor used in billions of cameras, and was inducted into the National Inventors Hall of Fame and the Space Technology Hall of Fame. Prior to joining Dartmouth he was CEO of two 100+ person companies – Photobit which he co-founded, and later Siimpel. From 1990-1996 he was with the NASA Jet Propulsion Lab at Caltech where he led image sensor R&D, and from 1984-1990 he was on the faculty of the Engineering School at Columbia University. He has authored over 250 technical publications and holds over 140 US Patents. He is a Fellow member of the IEEE and received the IEEE Andrew Grove Award in 2009.