OPTICS-INSPIRED Student Entrepreneurship

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The business environment for today's scientists and engineers is dramatically different from that which existed only a few years ago. To help young technical professionals develop the strategic and human relations skills necessary to succeed, Rhode Island-based Brown University, working alongside local businesses and with funding from the National Science Foundation, has implemented a two-semester entrepreneurship program. In its five-year existence, the program has spawned 12 student-run simulated startups, some of which have been spun out into actual operating companies.

The worldwide growth of university-based entrepreneurial education over the course of the past decade has been fueled by a number of factors. They include strong support from alumni and external constituencies, the visibility and status in society of successful entrepreneurs, universities' desire to derive marketable technologies from the research programs they sponsor and recognition by governments of the vital role that small companies can play in stimulating local economies.

Campus entrepreneurship programs have traditionally been based in schools

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Students at work in the entrepreneurship room at Brown. The room is modeled after an incubator setting.

of business or engineering, but today such programs are gaining acceptance throughout the university community. They are increasingly being viewed not only as an educational and training tool but also as a way to inspire students to pursue the traditional values associated with capstone projects that integrate the components of an undergraduate education into a complete experience.

It is our experience that students in a variety of academic areas are attracted to the opportunities offered by entrepreneurship. Entrepreneurship courses tend to be viewed by students irrespective of discipline as a way of enhancing their ability to achieve long-term career goals. Today's students find value in the competencies and skills associated with entrepreneurship: leadership, teamwork, opportunity assessment and risk assessment, communication and creative problem-solving. The entrepreneurship experience fosters independence, innovation and the awareness that each student is, in a sense, the "sole proprietor" of his or her own future.

A revolution in science and engineering

The science and engineering sectors are undergoing a metamorphosis in terms of the skill set and mindset that characterize successful practitioners. A significant percentage of today's science and engineering graduates will quickly find themselves in environments very different from the ones that traditional science and engineering programs have prepared them for. In the United States today, economic growth is tied to small, high technology startups in which a few key professionals play critical roles. Technologists working in start-up environments cannot afford to engage in compartmentalized thinking; they must possess the ability to communicate with potential customers, investors and business professionals. Technologists in a contemporary startup must be aware of market conditions, as well as of legal, environmental and human resources issues. Engineering and science students are often ill-prepared for careers at small technology companies where strong communication and innovation skills are vital.

Faced with this reality and the challenges it entails, we have designed a two-semester course at Brown University based on the concept of technology-based entrepreneurship. With assistance from the National Science Foundation and the local business community, the entrepreneurship sequence has been offered at Brown for the past five years.

The parallel track model

The Brown entrepreneurship sequence consists of two courses offered in successive semesters. Although separate course credit is awarded for each semester, students are asked at the outset to participate in the entire cycle. With very few exceptions, students commit to the full year.

Several characteristics set the Brown sequence apart from other entrepreneurship programs. First, in the summer before it begins, faculty members identify a number of local companies whose employees agree to become the mentors of a student team. Each mentor company provides a group of students with seed technology that can serve as the basis for a simulated spinoff. Over the past five years, 12 technology-based student companies have resulted from our course. The model has proven equally successful with a range of mentors: large multinationals, small start-ups and sole-proprietor firms.

Partnership with a mentor company has two main advantages. First, the student team gets a rapid start on a technology-based project. It is highly unlikely in fact that, working on their own, the students could quickly identify and develop a technology to the level of sophistication provided by the mentor firm. Since the course sequence lasts only nine months, the delay involved in identifying an appropriate technology by another route would cut into development time to an unacceptable degree. Under this model, the students can enter the product development phase immediately at the beginning of the course. Since the mentor-seeded technology has already been vetted by the mentors themselves or others in their organization, initial concerns regarding the viability of the technology are greatly reduced. In many cases, the viability issue re-emerges at a later stage, when the time comes to find a market niche. At that stage, however, students are more capable of managing uncertainty and working through problems together. More often than not, basic research questions also arise immediately: they offer the group an initial opportunity to work collectively to solve problems.

From the participants' perspective, the course begins with the formation of three teams of six to 10 students each. An important feature of the program is the multidisciplinary composition of

Brown University's Entrepreneurship Model

Summer

Business Practice Track
- Faculty/mentors interact
- Seed ideas screened

Lecture Track
- Faculty organize outside lectures

Fall Semester

Business Practice
- Mentor provides seed idea
- Students refine idea
  - Market intelligence
  - Opportunities
  - Challenges
  - Design

Lectures
- Teamwork; intellectual property; technical marketing; business plans; time value of money; finance/funding

Deliverables
1) Preliminary business plan
2) Engineering designs
3) Presentations to mentor

Spring Semester

Business Practice
- Continue refinement
- Develop prototype
- Develop business model

Lectures
- Government funding; angel investment; venture capital; break-even analysis; start-up case studies

Deliverables
1) Full business plan
2) Working prototype
3) Presentations to mentors
4) Presentations to investors
5) Compete in business plan competitions

Positive Outcomes

- Experience for students
- Outreach to industry, community
- Interaction with government, private organizations
- Potential spin-out companies
- Spin industry expertise into university
- Enriching for faculty

Figure 1. Brown University's parallel track entrepreneurship model includes extensive practical experience and lectures.

the teams. The course is open to juniors and seniors from any academic discipline who wish to apply. Faculty carefully reviews the applications to create teams composed of a balanced combination of individuals with core competencies related to the envisioned tasks. An effort is made to ensure that no team is dominated by students of similar backgrounds; in other words, students concentrating in technical and non-technical fields are present in equal numbers in each group. Faculty attempts to evenly distribute the science and engineering students across the teams. The goal is to allow each team to benefit from the perspectives of people with backgrounds in the sciences, engineering, humanities and business. This arrangement makes it incumbent on students to develop an effective team with people from different backgrounds.

Our parallel track model, illustrated in Fig. 1, consists of a simultaneous practice phase and lecture series. In the summer before the course starts, at the same time faculty members are screening ideas and mentor companies, they also organize a group of outside guest speakers for the lecture component of the course.

Some of the topics covered during the lectures are: intellectual property, marketing, financing startups and team building. Rather than having faculty members attempt to cover such a diverse set of topics, we think it best to bring in experienced professionals to engage the class in their respective fields. Although this approach brings realism and freshness to the course, it also requires a considerable amount of orchestration because the topics must come at the "right" times of the semester and the speakers must be helped to gear their presentations to the level and background of the students taking the course.

Once the students have received the seed idea from the mentor company—a transfer that typically takes place a week or two into the course—the students "own" the idea and it becomes theirs to work with. The students refine the idea, spending a great deal of time identifying potential applications and markets. The students present their findings to the mentor company on two or three occasions during the semester; they are also expected to turn in a preliminary business plan and engineering designs.

These sessions, the first of which takes place about a month after the students receive the seed idea, are intended to make sure that they have properly understood the technology and its implications. It also affords them the opportunity to ask questions of the representatives of the mentor company based on the knowledge they have acquired so far.

The lecture track during the fall semester focuses on the nuts and bolts of entrepreneurship: teamwork, intellectual property, marketing, business plans and a handful of topics in finance. After the month-long winter recess, in the second semester students reconvene with mentors and continue development of their prototypes and business models.

The lecture series in the spring semester is aimed at introducing funding mechanisms for startups, with emphasis on non-dilutive capital provided by government agencies, angel investors or venture capitalists. In this phase, more attention is given to finance and cash flow, and the concept of intellectual property is refined in the context of the students' own companies. In addition to attending lectures by experts, the students formally present their business plans and technology to each expert. This allows them to obtain valuable feedback from seasoned professionals.

The deliverables from the course are a complete business plan and a working prototype of the technology. We also require students to participate in several business plan competitions during the spring semester, both on and off campus. Although our first and foremost objective is to provide students with a sound educational experience, there are several other positive by-products of the course. They include outreach to the local business community and the useful links it builds for the university.

There is also close interaction with government and private organizations involved in business development. There are, of course, the potential spin-out companies that can and do result from the program.

Finally, participation is a stimulating and rewarding experience for faculty: the program is a world apart from the

traditional lecture course that can become deadening if offered too long in the same manner.

The case studies

Here are case studies of two companies—Spectrosity and Anemitech—both of which were founded based on products that employ optical technologies.

The Spectrosity case

The Spectrosity team was composed of seven members, four of whom were technical and three of whom were humanities or social sciences majors. The group was seeded with a spectroscopically based product concept invented at Zebra Technologies, Warwick, R.I. The seed concept presented to Spectrosity was essentially a simple, inexpensive handheld spectrometer unit that flash- illuminates an object with a single, selected wavelength of light and then quantitatively detects the resulting emission or reflection of light of another wavelength from the object. Spectrosity's major strategic challenge came in choosing an appropriate market match for the core technology and modifying it to fit the niche. This group was handed a classic "hammer-looking-for-a-nail" problem. The technically based students initially dedicated most of their time to researching this particular kind of spectroscopy and its potential applications. As a simulated spin-off, Spectrosity initially engaged in researching three major industries that seemed to offer application potential: dental, food contamination, security/forensics. All these applications were eventually ruled out because of saturated markets and stiff competition in dental cosmetic applications, unattainable requirements of instrument sensitivity for food contamination applications and a relatively small market and heavy competition for forensics/security.

After several months of brainstorming and research, the team finally converged on an attractive new application: detection of gel electrophoresis, a chromatographic technique widely used in biology labs. The group focused on designing a new product derived from the existing spectroscopic platform. The application seemed to fit well with the platform, but the students were still in need of a robust market. Because the technology was not only effective but also inexpensive, the most attractive market appeared to be institutions of higher education.

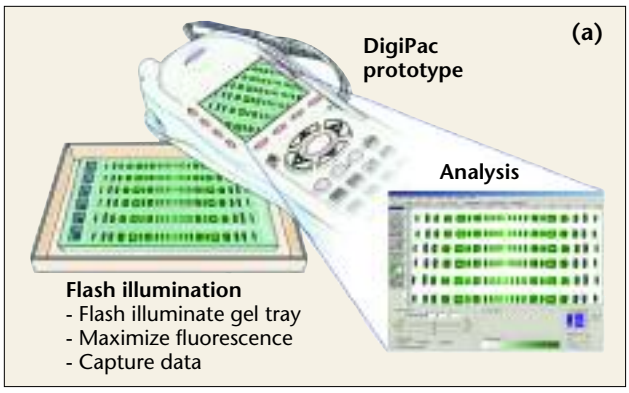


Figure 2. Illustration of Spectrosity's handheld electrophoresis device, the DigiPAC (a) and the actual prototype (b). Spectrosity designed the product for the higher education market.

The technology is, in fact, attractive as a teaching device for use in biology and chemistry lab curricula at colleges and universities. In conjunction with their mentor company, the students adapted the spectroscopic platform and coined the name DigiPAC, short for Digital Portable Analysis Camera [see schematic illustration of the DigiPAC in Fig. 2 (a) and first-generation prototype in Fig. 2(b)]. The market opportunity was based on university administrators' desire to do away with ultraviolet (UV) light tables for safety and space reasons and to replace outmoded film camera recording of gel plate results. The business model was enhanced to make the concept more attractive to potential investors and customers by offering an entire solution: a turnkey laboratory exercise package including gel plates and power supply consumables. In this way Spectrosity would develop with clients an ongoing market relationship based on the sale of consumables.

The Anemitech case

Although the other student groups operated with local company mentors, Anemitech's mentor was an emergency room physician affiliated with Rhode Island Hospital. Anemitech was one of our largest student companies, comprised of five technical and five nontechnical students. The physician mentor provided the group with an algorithm designed to analyze the red, green and blue components of digital images of the conjunctiva of the human eye.

The conjunctiva are the mucous membranes located below the lower eyelid. In this site, the blood vessels are accessible to optical examination since they are located very close to the surface of the tissue. Physicians have long used visual assessment of the coloration of the conjunctiva to make a preliminary judgment as to whether a patient is anemic. It has recently been documented however, that, independent of the physician's experience, visual analysis is subjective and prone to error.

When applied to eye images, the algorithm supplied by the physician mentor returns the patient's hemoglobin reading. The research data (obtained by the mentor from digital images for 60 patients) were correlated with hemoglobin data obtained directly from a blood test. The results showed that the technique might hold promise as a diagnostic tool.

It was suggested to the students that the formal analysis of the coloration of the digital images could provide a reliable, noninvasive measure of the hemoglobin content of the blood in the

vessels of the conjunctiva. The concept eliminates the subjectivity of the visual conjunctiva exam, along with the pain and expense of blood tests. To develop the concept, the algorithm had to be perfected, then integrated into a personal digital assistant (PDA) platform (Fig. 3). PDAs, now available with built-in cameras, are increasingly being used by physicians. The figure shows the student team and physician evaluating the device on a patient at Rhode Island Hospital. The student-developed business model had two components: a PDA with integrated software as a complete diagnostic package and separate software for physicians who already had their own PDA devices. They chose to market the product under the name EyeNemia; the slogan they coined was "improving the quality of life in the blink of an eye."

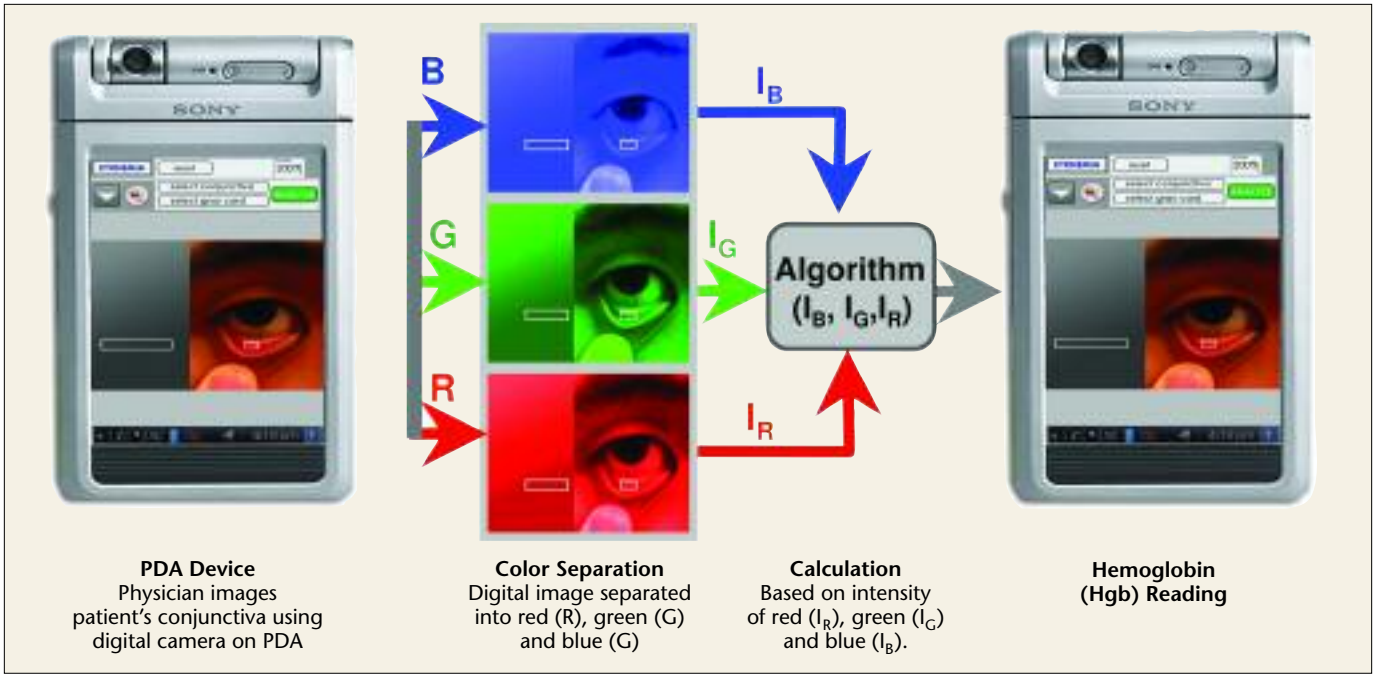
Reflections and questions

We believe we have developed a unique, robust entrepreneurship course model, which fits well with science- and engineering-based curricula. In many cases at Brown, because of the challenging nature of the technology component, engineering and science students have been permitted by their academic advisors to obtain independent study or design credit from the entrepreneurship course.

Faculty must be careful not to micromanage: the idea is to advise the teams at a distance, playing a role akin to that of a board of directors in the corporate world.

As faculty we have learned many lessons over the past several years. First, it is very important that the students have 24-hour access to a dedicated space, much as they would have at a real startup. To meet the need, we refurbished a room which simulates an incubator environment; here, students can develop their projects and business plans. Second, faculty must be careful not to micromanage: the idea is to advise the teams at a distance, playing a role akin to that of a board of directors in the corporate world. Faculty must allow students to develop their own ideas and solve their own problems. Finally, it is essential that the teams give numerous presentations to business and technology professionals outside the university; the feedback brings realism to the process, along with valuable business perspectives. Students must learn how important it is to be able to clearly present business ideas to a range of people.

The two most frequently asked questions regarding our course are how we handle intellectual property and how many course alumni become entrepreneurs after graduation. At the outset, each mentor company shares some intellectual property with its student team. This is done with the prior understanding that students will not be subject to any confidentiality agreements or restrictions, except as agreed to in advance by faculty. In general, in any case, confidentiality agreements and similar restrictions are discouraged. Consequently, the information that is generally conveyed to the team has either already received some intellectual property protection within the mentor company or consists of ideas that have not been developed to a point at which there is a basis for intellectual property protection. As compensation for their intellectual input and the investments of time and resources, mentor companies receive assurances that any additional intellectual property developed during the course will be theirs. If the company wishes, it may of course



surrender these rights to the University or to the student-created corporate entity. Over the years, this issue has been resolved in a variety of ways; it is common, however, for the mentor company to assign its rights to the students so that they can pursue the startup.

Most students who take the course have a desire to start their own companies sooner or later. We do find some who don't want to become entrepreneurs at all, or at least not right away. In several cases, two or three students have actually incorporated their companies and made a go at running them. New graduates are well equipped to start a small company because they are enthusiastic and have fresh knowledge and university contacts. Since most students have few commitments and responsibilities, at graduation they can proceed in the direction of choice.

On the other hand, student ventures generally lack a seasoned business professional to assist in the minefield of events that awaits in the real world and faculty cannot continue to mentor all the progeny of the course. For the new companies to be successful, they must attract experienced professionals and/or organize an advisory board. Although the university can help, the impetus at this stage must come from the students themselves.

Figure 3. How Anemitech's technology works: a digital image of the conjunctiva is taken by a physician using a PDA. The image is separated into three color components and analyzed by an algorithm, which returns a hemoglobin measurement in seconds (*above*). On the image on the facing page, emergency room physician Gregory Jay of Rhode Island Hospital, mentor to Anemitech, uses the technology as students observe.

We strongly believe in the importance for undergraduates of an entrepreneurial experience. Whether they pursue their own company or choose alternative career options, the skills learned in such a course—innovation, independence and communication—are vital to their future. One of the most heartwarming experiences a professor can have is to see a shy, reserved student transformed into a passionate co-founder of a company. Among students who take the Brown sequence, it happens all the time. Not only is entrepreneurship education beneficial to students, it is enriching for faculty and the participating mentors. Entrepreneurship education serves as a focal point around which faculty from different departments can cooperate in new and exciting ways.

The Brown course is designed to give students access to technology that ranges from optics to electronics and from materials processing to biotechnology. There is a deliberate attempt to keep the technology base broad because we want the teams to learn from their colleagues about developments in a wide range of technical areas, as opposed to becoming narrowly focused on any one sector. Optics has historically been a fertile area for new projects, both because one of the course instructors is active in the field and because we have tended to draw from a student pool with significant coursework and interest in optics and electronics.

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OSA Member

Further Reading

1. C. J. Creed, E. M. Suuberg and G. P. Crawford, "Engineering Entrepreneurship: An Example of a Paradigm Shift in Engineering Education," J. Engineering Ed., April 2002, 185-95 (2002).