*Int. J. Engng Ed.* Vol. 21, No. 2, pp. 239–256, 2005
Printed in Great Britain.

0949-149X/91 $3.00+0.00


# A Technology-Based Entrepreneurship Course*

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*This paper provides a brief description of experiences with a technology-based entrepreneurship course developed in an engineering program, but serving the needs of a liberal arts university. The course, started with assistance from the National Science Foundation and the local business community, has been offered at Brown University over the last five years and was first described in an earlier article [1]. The course model is designed to spin-in high technology product concepts into the university environment, which are further developed by an undergraduate entrepreneurship team and mentored by industrial professionals and academic faculty. This paper re-examines some of the key features of the course in light of the accrued experiences and addresses some of the more commonly asked questions, such as how the intellectual property issues are handled. In addition, we explore the impact the course has had on its alumni and their future plans, both in entrepreneurship and in business in general.*

## INTRODUCTION

ALTHOUGH 'entrepreneurship' has long existed as an important part of organized societies, the idea of educating entrepreneurs as such is a relatively new concept. In the 1960s, only about 10 universities in the United States offered courses on this topic [2]. Since then, the number of schools with entrepreneurship programs has increased significantly. In the 1990s, about 400 institutions offered programs in entrepreneurship [3]. Today, the number is closer to 700 [4].

Entrepreneurship programs are perceived by their graduates to have a strongly beneficial effect on their careers and lives. Of the students surveyed at the end of an entrepreneurship course at one medium sized university, 80% said they planned to start their own company at some point in their career. Of those, 75% did start their own business and 76% of these said that the entrepreneurship course played a key role in their decision [5]. At the very least, this shows that courses in entrepreneurship can nurture or help further develop an already existing interest in the subject. Another study by Vesper and McMullan demonstrated that entrepreneurship can be 'taught', in the sense that students who had taken courses in entrepreneurship made what were seen as better business decisions than did their counterparts who did not have an entrepreneurship education [6].

Even though entrepreneurship education could potentially play an important role in almost any discipline, participation in such programs is usually associated with students of business. Most schools base their entrepreneurship programs in a graduate school of business. In fact, of the 38 top entrepreneurship programs in the country (according to US News & World Reports and Success Magazine), only seven are located outside of a graduate business school. Within those 38 schools, only three have programs based primarily in the engineering school, though 21 of the non-engineering based programs are accessible to engineers [7].

Still, for an engineering constituency, entrepreneurship courses based mainly outside of an engineering department are not always viewed as optimal; while the business side receives strong emphasis, there is often a failure to integrate fully enough the very important technical and engineering design aspects that engineering students seek or find most interesting. It is important to bear in mind that just as there exist enormous variations among the individuals who would be considered successful entrepreneurs, there likewise exist many different successful models for entrepreneurship education. The course at Brown University was developed to suit its particular set of circumstances and constituency. Brown University offers five fully accredited fundamentals-based engineering programs that are very strongly integrated with one another in a single Division of Engineering. At the same time, Brown University does not have a traditional program of study in business at either the undergraduate or graduate level. Hence, in developing a program in entrepreneurship, it does not have a business school-based faculty upon which to draw. The course that is the subject of this paper has grown out of a long tradition in Brown University's Division of Engineering, of offering to the University as a whole a few courses that serve as an

* Accepted 16 February 2005.

introduction to business and technology management. The course, and how it was developed, has been previously introduced in a separate publication [1]. Details of many aspects are provided there. Here, some of the salient features are reviewed, and more recent case studies from the course are summarized. Also, this article takes up the important issues, not yet fully developed in our previous publication, of where the student teams take the projects beyond the time of completion of the course.

## THE BROWN UNIVERSITY ENTREPRENEURSHIP COURSE MODEL

The course normally involves setting up three student teams of 6 to 12 students each, and asking each to simulate a technology-based spin-off company. The experience actually consists of two one semester courses each of which carries separate course credit. It is, however, made clear to the student participants that there is a preference that both semesters be taken. Though there is no requirement that students actually continue for both semesters, over 90% always do.

The course at Brown University has several unique characteristics that set it apart from many other 'entrepreneurship' courses. First, the students are provided with a technology around which build their company. In the summer before the course begins, the course faculty identify and work with companies that become 'mentor' organizations for the class. These mentor companies provide an agreed-upon seed technology for a single group of students who are asked to create a simulated spin-off company that is broadly based around this technology. The seed technology varies widely from year to year and from mentor company to mentor company. For example, this past year, one group was given a device, another a material, and a third a patent pending concept. Over the past four years, we have formed eleven technology-based student companies as shown in Table 1. Our model has been successful when working with large integrated and multinational companies, such as Foxboro, and with small start-ups, such as Cell Based Delivery and Afferent Technologies.

The partnership with a mentor company provides each of the teams two major advantages. First, they have a rapid start on a technology-based project. It is unrealistic that, left entirely to their own creativity, the students could as quickly identify technology of the level of sophistication that is provided to them by their mentor company. Keeping in mind that the course has a firm nine-month deadline, the delay involved in identifying an appropriate and most likely unproven technology by some other route might well be unacceptable. When the students begin the course they are ready to engage in the new product development process, though more often than not, it is a preproduct development stage where many additional product redefinition and design needs are quickly identified. A second advantage of providing mentor-suggested technology is that this technology has already been filtered or vetted by at least one person knowledgeable in the industry. This greatly reduces initial student anxiety regarding viability of the concept, though this almost invariably re-emerges at a later stage of product research and development. By then, the students are better able to cope with such concerns.

The use of what is initially a strongly mentor company-driven product definition has been of concern to some to whom we have described our course. They have specifically been concerned with what might be called a short-circuiting of the process of opportunity identification. We wholeheartedly agree that opportunity identification is an important aspect of an entrepreneurial experience, and feel that it is, in fact, well represented in this course. What the student teams receive is not a well-seasoned idea, but something that is defined in very broad terms. While it is true that the members of the student team might never themselves have thought to pursue a market opportunity involving the particular technology that they have been assigned, this hardly diminishes the experience. None of the project ideas are yet anywhere close to the stage that would allow even one experienced in the business area to immediately write a successful business plan based upon them. There is generally an enormous amount of work yet to be done, both engineering design and market research, in capturing a true market opportunity that the technology may point towards. All that our approach does is to narrow somewhat the range of possibilities so that the paralysis associated with complete freedom of choice does not set in at the beginning of the course. In fact, it is common that our student teams identify new opportunities for the technology not seen by the mentors and they create new and/or additional intellectual property. In the end, most teams do experience the important opportunity identification phase of the entrepreneurial process through our course.

Another important feature of the course structure is the composition of student teams. The entrepreneurship course at Brown University is open, by application, to juniors and seniors from any of the departments on campus. The course faculty review the applications and assign teams, making an effort to provide each team with a mix of people who have skill sets related to the envisioned tasks. There is an effort made to assure that no team is dominated by students of similar backgrounds (students concentrating in technical and non-technical fields are more or less present in equal numbers in each group). Also, an attempt is made to evenly distribute the engineers across each of the three teams. This arrangement makes it incumbent upon the students to learn how to work with, and develop an effective team from,

Table 1. Table of prior companies

| Year | Mentor Company | Size | Student Company | Student Company Make-up | Technology |
|---|---|---|---|---|---|
| 1999–00 | Albany International | 6,200 employees worldwide | TS Prince | • Comparative Literature<br>• Materials Engineering<br>• 2 Organizational Behavior Management/Economics<br>• 2 Chemical Engineering<br>• Organizational Behavior Management<br>• Mechanical Engineering<br>• Materials Engineering/Economics<br>• Applied Math/Economics | Cage technology for filtration technology |
| 1999–00 | Comtec | 300 employees | IRIS Solutions | • Electrical Engineering/Modern Culture & Media<br>• Organizational Behavior Management/Economics<br>• Mechanical Engineering<br>• English<br>• 4 Electrical Engineering<br>• East Asian Studies/BA Engineering<br>• Economics/Urban Studies<br>• Materials Engineering/Economics<br>• Psychology | Electronic shelf label technology |
| 1999–00 | Foxboro | 76,000 employees worldwide | Intrinsic Systems | • 2 Electrical Engineering<br>• Business Economics<br>• 3 Chemical Engineering<br>• Computer Science<br>• Public & Private Sector Organizations | Wireless automation for control systems |
| 2000–01 | General Practioner | 3 physicians | Mdigital | • Business Economics/Sociology<br>• Computer Science<br>• Modern Culture & Media<br>• Computer Science<br>• Political Science<br>• Economics/Engineering<br>• 2 Electrical Engineering<br>• Computer Science/Organizational Behavior Management<br>• Comparative Literature<br>• Economics | Electronic medical records |
| 2000–01 | Zebra | 2,000 employees worldwide | Handprint | • 3 Economics<br>• Computer Science<br>• 4 Mechanical Engineering<br>• Art/Economics<br>• Engineering Management<br>• International Relations<br>• Classics<br>• Public & Private Sector Organizations<br>• Electrical Engineering<br>• Architectural Studies<br>• Organizational Behavior Management | Portable/wireless inkjet color printing |
| 2001–02 | Laserfare | 75 | Conformance Solutions | • Public & Private Sector Organizations<br>• 2 Electrical Engineering<br>• Materials Engineering<br>• Computer Engineering<br>• 2 Economics | Direct write technology |
| 2001–02 | Zebra | 2,000 employees worldwide | Piggyback | • Computer Engineering<br>• Computer Science/French<br>• Mechanical Engineering<br>• Engineering/Economics<br>• Development Studies<br>• Computer Engineering<br>• Public & Private Sector Organization | Integrated hand-held printer technology |
| 2001–02 | Afferent | 3 person start-up | Ferrosity | • Economics/Hispanic Studies<br>• International Relations<br>• Economics/Public & Private Sector Organizations<br>• Mechanical Engineering<br>• Civil Engineering<br>• Engineering/Economics<br>• Electrical Engineering | Magnetorelogeal fluids integrated in power tools to suppress vibrations |
| 2002–03 | Emergency Room Physician | 1 - no company, owner of patent | Anemitech | • Public & Private Sector Organizations<br>• Mechanical Engineering<br>• Chemical Engineering<br>• International Relations<br>• Political Science<br>• 2 Computer Science<br>• History<br>• Biology<br>• East Asian Studies | PDA tool to screen for anemia |
| 2002–03 | Zebra | 2,000 employees worldwide | Spectrosity | • Computer Science<br>• Business Economics/Public & Private Sector Organizations<br>• Computer Science/Business Economics<br>• Mechanical Engineering<br>• Psychology<br>• Public Policy<br>• Electrical Engineering | Low cost spectroscopic equipment for student laboratories |
| 2002–03 | Cell Based Delivery | 15 - start-up | NeMuTec | • Business Sociology<br>• Electrical Engineering<br>• Biology<br>• Biology/Public & Private Sector Organizations<br>• Civil Engineering<br>• Mechanical Engineering<br>• Engineering & Economics<br>• Political Science | Preclinical drug testing method |

people of diverse backgrounds. A summary of the students' backgrounds can be found in Table 1.

## MENTORS AND MENTOR-SEEDED IDEAS

Selection of the right mentors is paramount to the success of the course, and this needs to be accomplished before the course ever begins. Each individual mentor must satisfy two key criteria. First this individual must hold a high level position in his/her organization, and second, his/her company must be fully committed to the success of the student company. The first requirement ensures that the mentor can command sufficient resources in the parent company to allow the interaction to proceed smoothly. The course does not ask mentor companies to provide any cash or equipment donations (though sometimes the latter are offered). Here, the resource issue is one of access to key individuals within the organization and to important industry contacts outside of the organization. The second criterion ensures that a mentor will use his/her broad range of experience and resources to help the new company achieve a success, and that the mentor will not constantly be distracted by the more important issues of the day-to-day running of the mentor business itself. This latter point is actually not so much a function of the size of the mentoring organization, but more of how high a commitment a particular individual is willing to make to the course.

The course is designed to evaluate the ability of potential mentors to satisfy both criteria. While it is, of course, impossible to predict with certainty whether a particular mentorship will work well, the overwhelming majority have. All three of the companies that participated in the most recent year (2002–03) fulfilled the criteria very well. Mentoring the student company on behalf of Zebra Technologies, Inc. were Steve Petterutti, Vice-President of Engineering, and Robert Danahy, Vice-President of Marketing. Zebra manufactures a device for which they challenged the students to find a new commercial use, such that the mentor company could be a future manufacturing partner with the startup. A second mentor company was Cell Based Delivery (CBD), whose Chief Executive Officer, Dr. Robert Valentini, agreed to work with the startup team. He provided the student company human muscle tissue that could be grown outside the body. This material was the same technology as was being developed by the parent company for some specific medical uses, and he challenged the students to find entirely new commercial applications that CBD itself had no time to explore. The final mentor, Dr. Gregory Jay, is Director of the Simulation Center at Rhode Island Hospital. An experienced emergency room physician, Dr. Jay challenged the group to develop a commercial product based upon a clinical screening concept that he had been developing. In most cases, the lead mentor has an engineering or science background; however, in the case of Zebra Technologies, one mentor was an engineer and the other a marketer. We find this type of duo mentorship attractive to students so they can observe first hand the give and take and vital 'marriage' between engineering design and marketing demands.

Choosing the appropriate mentor-seeded idea is crucial to the success of the course from both the educational perspective as well the 'life after class' of the student startup company. From the educational perspective, it is important that the mentor-generated concept have broad design criteria so that students have some engineering design freedom. Our course deliverable for each group is a working prototype or proof-of-concept demonstrator, so it is important that either the company or the university have the appropriate infrastructure to accommodate the prototype efforts of each company. By using company infrastructure, very sophisticated and highly professional looking and functioning prototype can typically be constructed that may otherwise not be possible at the university. In addition, we also look for ideas that will challenge the students in ways not possible in a university setting where market criteria strongly influence engineering science and design principles.

From the perspective of actually creating a startup company at the culmination of the class, it is important that the mentor-seeded ideas NOT fall too close to the mentor company's core business roadmap. If this is the case, life after the course for the student team is difficult if not impossible. What we find that works best is if the mentor idea is one in which the mentor company does not have the resources or time to independently develop, or the 'pie in the sky' idea which is extremely high risk and the company would not develop using its own scarce research and development resources. What tends to work well in our experience is, if the seeded project is successful, the mentor company becomes a customer to the student spin-out, or one they would likely invest in as core business or diversification strategy.

## OUTREACH

The success of the course depends on drawing together a wide range of knowledge both within and outside the university. The course allows members of the Brown University community to reach out to the surrounding area, and also allows people from the surrounding area to reach into the university. The relationship with the mentor companies gives students exposure to local industry while providing the mentor companies with further potential intellectual property. During the lifetime of the course, and especially within the last two years, numerous articles have appeared in the local Providence media describing both the course in general and individual projects. The Providence

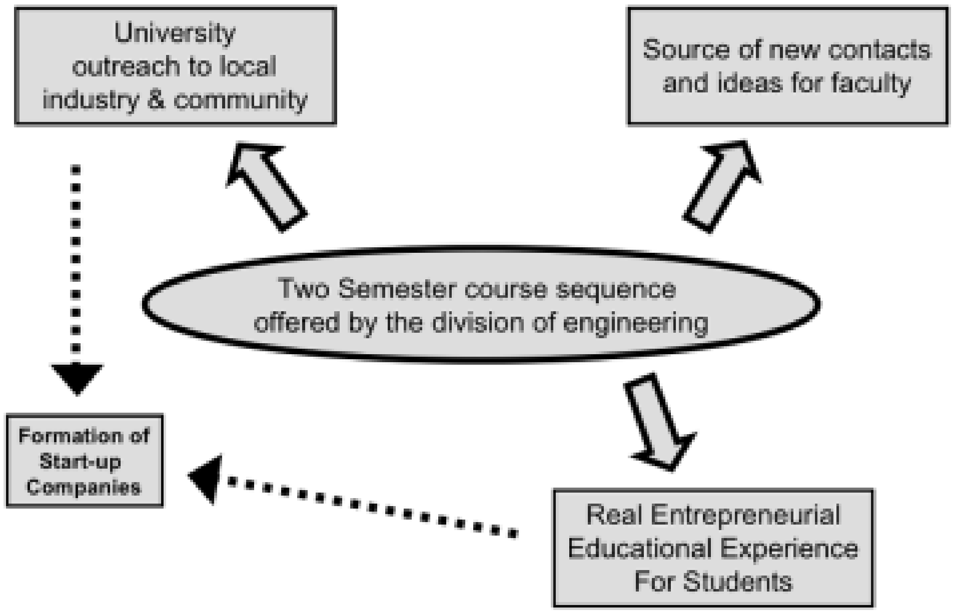


Fig. 1. Course goals and outcomes.

Journal, the largest daily publication in the area, has published two full pieces and used a quote from one of the mentors in their Sunday edition. These articles have generated recognition for the course and made it easier to find people in the business community who are willing to take part in either mentoring or presenting to the class. In addition to the local Providence media, Brown University's alumni magazine ran a story in the May/June 2003 edition, generating more attention and contacts for the course within the Brown University and local Providence community.

Our primary educational goal is to provide students with a real world experience while still in the academic setting. We have found that his course not only motivates many students to want to start their own company someday, but in other cases, it has also shown students that they do not want to follow an entrepreneurial career path, with its attendant demands and personal sacrifices. We feel that both outcomes are equally important in terms of the student education. We have also discovered that teaching entrepreneurship is personally challenging and intellectually rewarding to the faculty. It provides a dynamic and fascinating teaching environment, which in our opinion, is difficult to create in any other way. A summary of the course goals and outcomes is shown in Fig. 1.

## INTELLECTUAL PROPERTY

One of the most frequently asked questions regarding our entrepreneurship course is how intellectual property (IP) is handled. At the outset, each of the mentor companies shares some intellectual property with its student team. This is done with a prior understanding that students would not be subject to any confidentiality agreements or restrictions, except as agreed upon in advance by the course faculty (and conveying such information to the students is strongly discouraged by the faculty). Consequently, what is generally conveyed is either information that already has some intellectual property protection within the mentor company, or ideas that have not been developed far enough to have much basis yet for intellectual property. As a quid-pro-quo for their involvement in the course, there is an understanding with the mentor companies that any intellectual property developed during the course will remain the property of the mentor company, should they so desire. If they do not, they may surrender rights in the intellectual property to the university, or to the student-created corporate entity. Over the years, the mentor companies have made a variety of decisions on this point. Quite often, the mentor companies have assigned their rights to the students so that the students could pursue the start up. This is a two-edged sword, with the students initially content to control the IP that they develop, but then, later burdened by the knowledge that the responsibility for protecting the IP now falls entirely onto their shoulders. During last year's course, two of the three student groups filed provisional patents on what they had developed.

## COURSE STRUCTURE

The timeline for the course is provided in Fig. 2. This has already been described in our earlier article [1], so it is only briefly summarized here. Approximately one month before the course

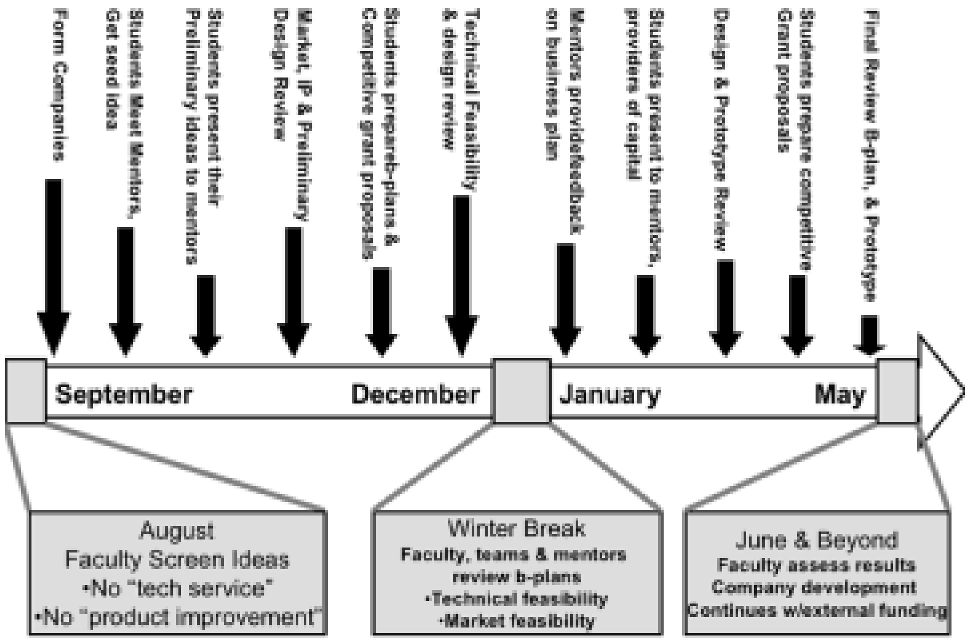


Fig. 2. Course timeline.

commences, the faculty visit potential mentor companies to select the technology and mentors. Student selection begins during the first week of the semester, and is based upon an application form that discloses their interests, experience, and academic record. There are no formal prerequisites for the course, except advanced undergraduate standing and a record that indicates the student will be able to cope with the workload. Although we ask the students their preference for the technology, the faculty reserve the right to balance the core expertise of the students to fit with the proposed projects. This seems to work quite well even if a student does not get assigned to the technology team of his/her choice. The faculty choose the teams during the first week.

Within the first two weeks of class, the student teams first meet with their mentor companies, at the company site, to be briefed about their technology. The students make a follow-up visit to the mentor company, roughly a month later, to ensure that they have correctly internalized the technology and to explore further the constraints on the technology and marketplace, once they have a better-developed sense of that technology and have had a chance to do some preliminary market research on their own. Following this are bi-monthly (or more frequent, as needed) visits to the mentor companies. At the end of both semesters, each team must prepare a comprehensive business plan and report on the status of their startup company and the project.

The course meets for three one-hour sessions a week. These times are reserved for lectures on general background information, and when not needed for this purpose, the course faculty meet with individual groups to check on progress. Most of the students' work for this course was completed outside of class hours. In addition to the regular class meetings, every group held a 'company meeting' (without mentors or faculty present) at least once a week.

The faculty organizes the course calendar and gives some introductory lectures on a number of subjects. A great deal of the background material is normally provided by guest lecturers or visitors arranged by the course faculty. Drawn from both the local and broader business communities, these individuals provide the insights of those actually engaged in the practice of entrepreneurship, from one perspective or another. At times, the role of these visitors is to critique the presentations that students prepare concerning their businesses. During the first few weeks of the course, the students received lectures about team building and leadership, management and company structure, value creation, intellectual property and marketing. We ask the students to postpone any decisions regarding their individual roles in their companies until after the initial lectures on team building and leadership.

The next part of the course curriculum involves a series of lectures given by entrepreneurs. Each of these lectures describes the hurdles to starting a company and some lessons learned. Jason Harry, Chief Executive Officer of Afferent Technologies and a mentor last year to the Ferrosity team this year, gave a lecture entitled, 'I Know What I Know When I Know It' in which he described the importance of being persistent, and in which he offered counsel about how to deal with critiques of the students' business ideas by 'experts'.

In the mid to late October, local business support professionals are brought in. A corporate lawyer explains the process of incorporation while the head of Brown University's technology transfer discusses how value creation from intellectual property works. Finally a representative from a local venture capital firm describes the current investing landscape and offers advice on startup funding. The ordering of lectures, as well as their timing, varies from year-to-year, depending upon the availability of the lecturers. There does not appear to be one truly optimal ordering of topics. Our experience suggests that it is important to have the teamwork and organizational lectures first, before the groups develop a rigid structure (that they might come to regret later). Also, it is important to introduce intellectual property and marketing somewhat early.

Concurrent with all the lectures are sets of assignments, often based on the week's lectures, in which the student teams are asked to, for example, research any conflicting patents, describe their market, make lists of current and potential customers, come to closure on a list of technical product specifications, etc. During periods in which no guest lecturers are scheduled, student teams give presentations on their findings to their classmates and faculty, who critique the presentations and probe various details, much as would a potential investor.

Towards the beginning of the second semester a few important 'nuts and bolts' lectures take place, such as the discussion of financials (which were more briefly introduced during the first semester). During this semester most of the class periods are utilized for developing the students' own business presentations. An effort is made to permit all students an opportunity to develop stand-up oral presentation skills during the course. During second semester there are again many visitors to the class. During this time the visitors' role is mainly to critique student business plans and to offer advice from the perspective of potential investors. While the talks for the first semester normally have specific, narrowly-defined topics, the talks second semester tend to be overviews of the companies and their product.

Assigning grades to the students after each semester is a difficult task for faculty. Grades are based on several criteria, which include student participation, mentor feedback, self and colleague evaluations (described in our earlier article [1]), and the student/faculty interview at the end of each semester. Even though the process may seem somewhat subjective, the faculty become so involved in the course and get to know the students so well, that assigning a grade at the end of each semester is not as difficult as it may first appear.

It should finally be noted that throughout the course, the students have full access to a large entrepreneurship room that has been set up for their exclusive use. It contains workstations, carrels, whiteboards, conference table, telephone, fax and copier. This facility is very heavily utilized and is a focal point for much course activity. In addition, most groups also find very valuable access that is provided to a rapid prototyping facility, containing four rapid prototyping machines of various kinds. This is a state-of-the-art facility, allowing automated rendering of parts in plastic or wax, from CAD designs. Use of these facilities is essentially free of charge to the student teams.

## WRITING ASSIGNMENTS AND COMPETITIONS

The main writing assignments for the course consist of full business plans, submitted at the end of each semester. In addition, during the first semester, what amounts to 'chapters' of the business plan are required as formal writing assignments during different points in the semester. Preparation of the final draft plan, by the still relatively inexperienced teams, works better during the first semester if the plan can be pulled together from the different pieces that were discussed in a more leisurely manner over the course of the semester. By second semester, the teams build upon what was prepared as a draft during first semester. The final plan is often significantly different than the first semester draft, as business concepts, technical understanding and market research begin to gel. Although the business plan prepared at the end of the first semester is 'rough', we find it important to push the students to do it in order to help them organize their thoughts. It is during second semester that organized marketing survey results generally become available (though some preliminary data are usually obtained in first semester), and that initial prototyping progress reveals where product redesign might be needed.

Alongside the main business plan preparation activity, student teams are strongly encouraged to enter business plan competitions. Student teams enter a variety of business plans and grant competitions as part of the coursework for the class. For example, the Brown University Entrepreneurship Program (EP, an independently run student club) holds a $1,000 elevator speech competition at the end of the first semester and a $25,000 business plan competition at the end of the second [8]. The student teams are encouraged to participate in both of these activities. The teams are also provided with information about how to file for NCIIA (National Collegiate Inventors & Innovators Alliance) grants, and virtually all teams do [9]. The NCIIA grants provide up to $20,000 in cash to student-run startup companies. In addition to these opportunities, teams often find other grant opportunities of various kinds; for example this year, one team found five other opportunities that it applied for during the last two months of the course, including the Oxford Business Plan competition [10]. Companies that have continued after graduation have filed for numerous government grants including Small Business Innovative Research (SBIR) grants.

The course faculty has continued to provide mentorship for these groups beyond the course. In the case of the NCIIA grants, university faculty must officially serve as the Principal Investigators on the grants and the general course faculty continue on in this role as well. We have been fortunate that four of our teams have won NCIIA awards (Handprint, Ferrosity, Conformance Solutions and Piggyback). It is important for institutions contemplating beginning coursework activity in this area to recognize that success achieved in that effort will inevitably carry with it a commitment beyond the classroom.

## WHAT STUDENTS DO AFTERWARDS

Brown University's experience with the entrepreneurship course is still somewhat short term. It is not yet possible to report on what students do as a career, since in most cases those careers are still in a formative stage. It is easier to report on what student alumni of the course go on to do in the near term.

A diverse group of students take the class, and there is an equally wide range of future plans within this group. Some students accept jobs at companies varying in scale from Fortune 500 to startup, from financial services to auto sales. A significant portion of the class pursued graduate school in fields such as engineering, political science, computer science, and law.

Almost all of the students felt that taking the class had some impact on their future plans. Those students who continued with their projects (through additional post-course funding) found themselves on completely different career path from what they had expected. None of these students had planned on creating a startup right out of college. Other students were encouraged to try different career paths than they might otherwise have explored. For example, one of the computer science majors took a summer internship in the product marketing division of a software company. She credited the course with increasing her interest in the area and giving her the skills sets necessary to feel comfortable applying for such a job. For some, the class confirmed their ideas about what they should do in the future. One engineer said that taking the course taught him a lot about all aspects of the startup business, and made him more committed to sticking with the purely engineering side. Other students decided to stay with their original fields of concentration, but decided that they liked a small company environment, and decided to focus on smaller firms in their job search. Some students felt the effect of the class immediately, whereas others admit that it changed what they saw themselves doing in the future. Quite a few students were interested in the possibility of creating a startup when they are older.

There are a number of students, particularly those who were juniors when they took the course, who do carry the venture forward beyond the course. Most have the benefit of continuation funding to a limited amount (less than $20,000 from, for example, NCIIA). These groups have met with varying degrees of success, and the story on several has yet to be concluded. One major impediment to success comes when the continuing students become seniors; it has been particularly difficult for groups to maintain momentum during the following academic year, under the competing pressure of coursework. Still, a special alumni business incubator room was established to accommodate these groups. It is equipped with workstations, conference table, telephone, and the alumni groups also have access to the facilities in the main entrepreneurship course facility down the hall. There is also continued access to the rapid prototyping facilities that are key for certain projects. The main issue for these groups is, generally, securing continuation funding. At this stage, even though the course faculty continues to mentor to some degree, the responsibility of sustaining the operations has shifted to the student team itself. By this point, the student team is generally down to 2 or 3 individuals, since it is difficult for the students to manage or fund a larger operation. One of the challenges for the institution is to see how it can enhance the chances for success of these alumni teams.

## WHY MOST STUDENTS DO NOT CONTINUE WITH THEIR STARTUP

The course faculty always emphasizes to the students that they have an opportunity in the context of this course to actually create their own job. The students are also always reminded by various course visitors that the downside risk of failure of their ventures is exceedingly small, at this age. Still, relatively few choose to continue on with their teams to actually launch the venture. It is instructive to look at why this is so.

Every year, on-campus interviews for large recruiters come earlier and earlier. Nowadays, some students return to school for their senior year with job offers in hand, while others receive theirs in the first month or two of classes. Seniors have a hard time deciding to continue with the course-generated startups, because at a time when most of their peers are making final decisions about what jobs they plan to pursue, course participants are just beginning to understand the product and market they would like to be working with. At this point, the entrepreneurship course is still in the incubation stage, and it is difficult to pass up a guaranteed job for something still far less concrete. This is especially true during a low-growth economy where most startups are having difficulty in finding funding.

Juniors, on the other hand, have had a full year with the technology when they first start to make their post-graduation plans. At this point, many of the companies have been able to secure some funding. Here, other factors come into play, as noted above. It is, however, predicted that should one of the course-generated companies mature into a success, the number of students willing to pursue their companies after graduation will significantly increase.

The course faculty was initially surprised by the apparent conservatism of many of the students in choosing their career paths. When asked whether they would not seriously consider continuing with the job that they have defined for themselves in the course (since it is generally a very real option) most would generally demur. Apart from the considerations of competing job opportunities discussed above, what might be a major factor here is the disruption caused by the end of semester, involving the disbanding of the team as they know it. They see very clearly, having just lived through it once, how much effort is involved in setting up a functioning team, and are reluctant to go through the process again, even though the product itself remains exactly the same. Of course for others, the financial risk associated with possible failure of the venture is the overriding consideration. For those student companies that do continue on after the course, they are usually composed of 2–3 students. These are the very enthusiastic students who became core to the company.

## STUDENT PERSPECTIVE ON THE COURSE

*Group size*

The size of the groups last year varied from 7 to 10. Although the size of a startup company at this stage of development is often considerably smaller than this, having slightly more students in the groups is good for certain reasons. First, since the students are only devoting themselves part-time to this activity (they are carrying full course loads), more hands are needed than might otherwise appear appropriate. In addition, the level of effort devoted to the course by different students is highly variable. Thus each group unfailingly ends up with a smaller core group who really put in major effort. The final reason is again related to post-graduation plans. Most students do not elect to continue with the company, so having a larger group makes it more likely that a reasonable number of people within the group will be able to continue the effort after the school year.

It was noted above that over the years, the size of teams has actually been varied from about 6 to 12. Experience has suggested that the lower end of this range probably yields the best compromise between the educational value of the experience and the resources expended. There are several drawbacks to setting up groups as large as 12 students. One is easily anticipated: there is too much of an opportunity for some members of a group to 'hide in the corners'. Regular individual assignments and a required rotation of presentation duties within the group can, to some degree, ensure that all members stay engaged, even in a large group.

What is actually a greater problem is the unrealistic burden that large size places on the group to set up a management structure in order to effectively utilize all of the available personnel resources. As described in our earlier article [1], the faculty try to act in a 'board of directors' role, as opposed to a managerial role. Hence, it is self-identified group leadership that shoulders the burden for managing these resources. The student leaders, with rare exceptions, are not yet up to the task with such a large group (particularly since they have no authority to fire or reward). Inevitably, friction develops within the larger groups when it is perceived by some members that other members are not 'working very hard'. There is rarely the ability on the part of the students to make a management adjustment to correct the situation once it is perceived to exist. It is therefore better to start with a smaller, more easily managed group, which is more reflective of what might exist in a real startup situation.

To decrease the team size to fewer than six would be an option that obviously comes with a higher degree of expense in terms of educational resources. For a given class size, the smaller the group size, the more mentors need to be identified, and the greater the logistical problems of arranging adequate access to the mentors. It is difficult enough to deal with three groups, when class meetings need to be scheduled to fit into ordinary class slots, and each class slot has to allow time for interaction with all groups. Perhaps relaxing some of these constraints might be an option in programs at some other schools, but it is not at Brown, where the curriculum is simultaneously constrained by limits on numbers of courses a student can carry, by ABET programmatic guidelines, and by the requirements of a common core.

*Considerations in group selection*

One of the first things that the faculty must do in organizing this course is to set up viable teams with the appropriate core expertise to 'tackle the problem'. At various times, a few students have suggested that the process would work better if the students could select their own team, as opposed to being assigned to one. When the question was more broadly examined, the students within the class almost universally rejected the idea of picking their own team, for a variety of reasons. There was one major disadvantage that was cited many times—it might prove impossible for the students to create three diverse teams if they were allowed to choose. Since students in the course come from such diverse backgrounds, most do not know enough about other people in the course to effectively assemble an entire team. Then there was concern that friends would be pressured to choose friends, most of whom come from a similar disciplinary background and thus leading to imbalance in teams. A student also noted that in most companies, people do not have control over whom they work with, and most of the time they do not know colleagues before being forced to develop a working relationship. In short, the course offers a realistic team-building environment. Although most students agreed that giving them choice over the membership of their own team would not increase the likelihood of its success; teams that got along well were perceived as having more success than those that did not.

Students showed more interest in selecting the technology that they worked with than the team that they worked with. The perception was that the students who had genuine enthusiasm for their product worked harder and produced more than those who did not. Here, an argument can be made for picking teams that are in some sense empathetic to a technology, in order to increase the buy-in to a project and team. The practical reality is, however, that only certain mentor companies and their associated technologies are available at any one time. To offer choice, only to withdraw it in the face of an imbalanced selection on the part of the students, would certainly risk getting off on the wrong foot in the course.

*Differences from a 'real' startup experience*

When students were asked how the situation in their course did not mirror what they perceived as facing those involved in a real startup, most responded 'outside commitments'. It is immediately clear to all of the students that creation of a successful startup requires total commitment to its success. On the other hand, in this sort of a course, none of the teams were capable of the fulltime commitment that is required, because they are made up of fulltime students carrying full course loads (not to mention involvement in athletics, and other extracurricular activities). In addition, the students who are drawn to this course are often those who already play a leadership role in another organization—captain of a sports team, organizer of a student club, etc.

This fact quickly leads to a realization that while a course of this kind offers a high degree of realism, it is artificial in the degree of commitment that can be expected from the individual team players. This is exacerbated by a healthy skepticism concerning the commercial viability of the assigned technology. Almost everyone in all of the groups at some point had some doubts about whether the technology could work, or, even if it did, whether anyone would want to buy it. Though the faculty and visitors emphasized that such concerns were all part of any real business development process, the fact that the student commitment to the company was only one of many they had during the semester, did not instill in the teams the essential belief that the company had to be *made* to work. The cost of walking away from the business was still low, though not zero. Some students were definitely in the position of needing the course credit, and being unable to simply give up when the going got tough. Here, an up-front buy-in to the technology would perhaps help in developing a greater degree of commitment.

However, the companies created in this course also benefited from their insular, academic setting. In essence, none of the companies had any capital 'burn rate' for their first nine months. As already noted, the groups had access to many of Brown University's facilities, company infrastructure in many cases, as well as to the entrepreneurship room and facilities therein. Additionally a small amount of funding was made available to purchase items needed to build a prototype (as well as for purchasing small amounts of supplies). This removed many of the concerns that do require significant amounts of management time in a real startup, and permitted the teams to focus on core business development issues.

*The course as a valuable adjunct to an engineering curriculum*

This course is offered by the Division of Engineering at Brown University, and has a special place within the programs of that academic unit. In certain engineering concentration areas, it can count towards required design credit. It is appropriate to examine how this course fulfills the needs of this particular important constituency. (About half of the students in the course are engineers.) The course also adheres to important new Accreditation Board for Engineering and Technology (ABET) criteria (www.ABET.org), especially in areas which are hard to 'touch' upon in the conventional engineering curriculum such as:

- the ability to function in a multidisciplinary team;
- the ability to formulate, identify and solve engineering problems;
- an understanding of professional and ethical responsibility';
- an ability to communicate effectively;
- an understanding of the impact of engineering in a global an societal context;
- a knowledge of contemporary issues to name a few.

It is often said that engineers are inclined to design things with as many 'cool' features as possible, because they are not taught to realistically assess and act on market information. Commercialization of their designs is left as a concern for others to deal with. The students recognized that this class turns that model on its head. From the beginning of the design process, the engineers needed to consider what the customer wanted and, more importantly, what the customer would buy. For example, when the computer science major designed the interface for Anemitech's EyeNemia product (see below), he made it as simple as possible because the company had found through marketing research that most doctors are not willing to spend a lot of time to learn how to use an unfamiliar interface. In a traditional computer science class, the student pointed out that he would have added a lot of extra, complicated features to the design, in the effort to secure an 'A'.

Besides changing the way they approached the design problem, the course also confirmed for engineers the importance of certain non-technical skills required for success in business. One of the engineers reported that the course had made him realize how much he had learned in his four years at Brown University. He and some other engineers in his group tried to explain some of their product's technology, using the terminology of basic principles learned in core engineering classes. At the end of the explanation, the non-engineers in the team asked him to start over, in English. He then realized that he had mastered concepts that were not everyday knowledge, but at the same time, he needed to learn how to break down the technical concepts into layman's terms. This need was reinforced when almost every week during the second semester, the groups presented to potential investors, many of whom had no technical background.

Another important business skill is the management of time. Most of the assignments needed to go through a review by several people in the group, before being turned in. Although the faculty would give a final deadline for submission of a report, they did not define subtasks and deadlines for individual members of the group. Group members quickly learned the importance of making good estimates of how long it takes to accomplish parts of a project and working towards a deadline. After a while, the engineers, and everyone else, in the group learned the importance of allowance for unpredictable setbacks in the timeline.

For many, the final group evaluations reflected a change in the way that they looked at themselves and their productivity. The evaluations went well beyond measuring an amount of time invested in the activities. The company evaluation forms focused on how much was accomplished relative to group-defined goals for the person. They also emphasized the value of the overall contribution to moving the technology forward towards commercialization. Gone forever was the simple world of exams with right answers and direct competition with student peers.

The above testimony comes as no revelation to anyone familiar with the business world, nor is it anything surprising to those involved in teaching entrepreneurship elsewhere. The point is really that when the testimony on behalf of this type of course is as strong as it is, it needs to be noted. The students to a very great degree view this course as the bridge they were seeking, between their academic pursuits and the real world that lies beyond.

*Engineers and patents*

Although several of the upper level engineering classes at Brown University touch lightly on the topic of patents, for most of the engineers in the class, the entrepreneurship course was the first that dealt seriously with the topic. During the first semester, the class had multiple lectures about the topic. First, one of the course faculty gave a two-lecture overview on the basics of a patent. Following this, an intellectual property lawyer for Brown University provided the students a deeper understanding of how patent law applied to their projects. In addition, this past year we were fortunate to have an employee from the United States Patent and Trademark Office (USPTO) lecture on the inner workings of the USPTO and how patent examiners evaluate patent applications. At the end of the three-lecture series, each group was charged with collecting any relevant intellectual property, documenting it, and formally presenting it to the rest of the class. In each group, an engineer took control of this process. This prepared them for second semester when two of the groups decided to file their own patents. Again, an engineer in each group championed the process. The engineers who worked with the patents generally enjoyed the process. One engineer liked the process of working with patents so much, that he changed his career plans and decided to apply to law school with the goal of moving into IP law after graduation.

## CASE STUDIES

This article closes with three very brief case studies, describing in more detail what the teams experienced when faced with three very different technology opportunities. The section is organized around the different teams and each is titled with the name that the student team itself selected for its company (trademarks applied for).

*Spectrosity*

Spectrosity's mentor company, Zebra Technologies, Inc. has already served as a mentor company in the course for three years prior to this most recent experience. At the beginning of the year, Steve Peterutti (VP of Engineering) and Robert Danahy (VP of Marketing), presented the group with a handheld device that the company had developed in response to the needs of another customer. The device is essentially a sophisticated digital camera-type device, which is capable of taking pictures of objects illuminated by flashes of certain selected wavelengths. The device had a small onboard processor and memory component. They provided the students two examples of uses they had researched in the past, and asked them to design something different. Their only constraint was to stay away from a certain security-related market since the company currently had an outside consultant working on that field.

Spectrosity had the smallest student group, with seven members, four of whom had technical backgrounds: two computer scientists, an electrical engineer and a mechanical engineer. They were the first of the three groups to define a company organizational structure in the fall semester. The leadership of the company, both the CEO and the executive vice-president, were technical people. The group members each chose their own positions and selection of the CEO was decided on a basis of who wanted the job and felt as though he/she could commit the time to doing it. Originally, one of the computer science majors became CEO, but during the second semester her other course workload became such that she passed team leadership to the group's mechanical engineer. All of the non-technical majors chose to work at what they broadly termed public relations (but including the marketing function), while the remaining technical members created specific job titles for themselves: Technology Advisor & Research Coordinator and Director of Engineering.

Spectrosity's biggest struggle came in picking a use for their technology. They had clearly been handed a classic 'hammer looking for a nail' problem. A photograph of the final prototype is shown in the Fig. 3 (a). What they had was essentially a handheld spectrometer unit- it could excite an object with one selected wavelength of light, and then quantitatively measure the resulting emission or reflection of light of another wavelength from the object (see Fig. 3). The engineers in the group initially spent a great deal of time researching spectroscopy and different possible uses for it. Originally Spectrosity looked into three major fields: dental/medical records, food contamination, and forensics. They liked the possibility of characterizing tooth whiteness since this is a key step in tooth replacement procedures. The technology seemed easily capable of achieving success, but the field appeared saturated with competitors and the team could not discern a way to add the needed value. The team also looked at the possibility of identifying food contamination, where there seemed to be a real market need. The engineers on the team found that their technology was not sophisticated enough to allow determining enough types of contamination at low enough levels to permit an obvious market to be identified.

Meanwhile, Zebra's outside consultant did not identify any apparently interesting commercial applications in forensics and security. The mentor company then allowed Spectrosity to explore this field. The results of their marketing surveys led to the same conclusion, though: the device could not successfully compete with the current products, for any number of reasons.

The indecision about application for the product made the regular first semester assignments for the class difficult, because the group was continuously moving from one application to another. Most of the presentation feedback they received during the first semester tends to be discouraging. The group spent their first semester meetings evaluating different ideas and reporting on research they had done on prior ones. Finally, in November, the group began to look into characterizing gel electrophoresis gels, which seemed to require capabilities as could be provided by a product redesigned from the basic Zebra platform. Electrophoresis gels need to be excited using an ultraviolet (UV) light table, and the results were often recorded using an ordinary Polaroid-style film camera. The platform that they had could replace many of these outmoded elements, and do so cost effectively. From there, the team moved in the direction of creating a complete gel electrophoresis lab kit, which would find a market in educational institutions due to the simple, low-cost modular nature. Even though they had found a promising use for the technology, they were initially reluctant to commit time and resources to this particular application. For the next few months they continued to brainstorm and explore other ideas, but by February, they decided to focus exclusively on the lab kit, potentially a $1.2 billion market.

Despite some difficulties deciding on a technology application, Spectrosity enjoyed some early successes. They were one of five finalists for the Brown University Entrepreneurship's Elevator Speech competition where they presented the food contamination monitoring idea. By the end of the first semester they had produced a business plan and had raised a small amount of seed capital, sufficient to start a website.

Once they had decided on a general product area, the company needed to develop a prototype. Again the technical side of the group researched the selected gel electrophoresis biology experiments. They developed contacts in Brown University's own Division of Biology and Medicine among the faculty who could be potential customers for the product. The product itself required some mechanical engineering, and a computer science major was assigned to modify the device's existing operating code and make it suitable for the biological laboratory application. The assignments within the team involved most members working on both technical and non-technical aspects; the engineers were, however, concerned that the business people needed to become more engaged in the technical aspects of the product. Most members of Spectrosity felt that their biggest strength, diversity, led to their biggest weakness. During brainstorming sessions, everyone on the team had different ideas, and the ideas which ended up being implemented were those championed by the loudest and most persistent voice.

Throughout the class, and especially in the second semester, visitors were invited to the class to hear each company's '15-minute pitch'. The visitors consisted of potential investors, advisors, industry people, and reporters. The first semester Spectrosity had struggled with the presentations because they did not have a clear idea of where

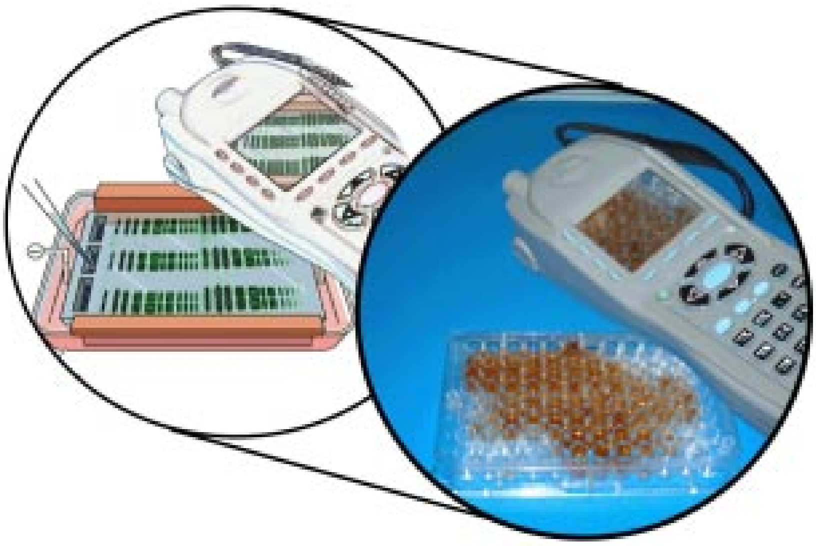

Fig. 3. The Spectrosity product: A handheld laboratory spectrometer.

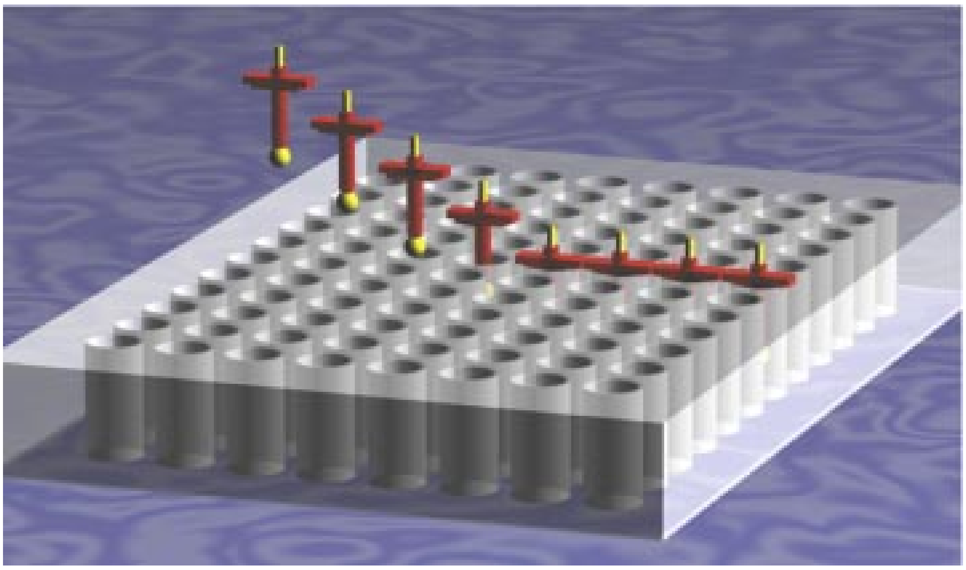

Fig. 4. The NeMuTech human tissue-based pharmaceutical screening product.

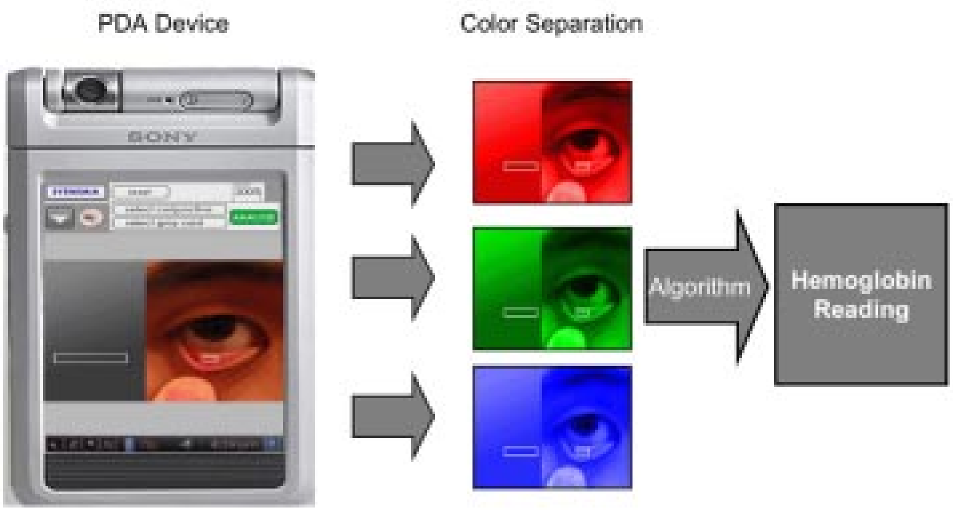


Fig. 5. The Anemitech PDA-based anemia screening tool.

they wanted to move their product. Company presentations during the second semester went much better. While they still received criticism, most of it was rooted in a firm belief the idea could work. Although most of the group was very busy with activities outside of the course during the second semester, they still managed to move forward with their concept and prototype. Towards the end of the second semester, Spectrosity filed a provisional patent on the concept of characterizing the results of an electrophoresis experiment using a UV flash device instead of a constant light source.

The final presentation of the group to the mentor company was well-received, and there was a feeling on the part of the mentors that the business concept could actually be implemented. They went so far as to suggest that the team had uncovered one of the most promising applications that they had seen for the device. In addition to the talk, the group also gave the mentor company mock-up models of the system components and a software interface for the electrophoresis experiment. They also packed together a kit that included all of the consumables needed for the experiment, as would be sold in a package to the university customer. The mentors asked the group to make a copy of the business plan and pull together any other supplementary materials possible so that they could forward the idea to company headquarters, and the results of the further consideration are not yet known.

Ultimately, the group lost momentum when the key members of the technical side of the team left for graduate school. Our experience has shown that technical expertise is clearly the 'limiting resource' in making a success of these technically-based startups. When the number of students who are technically up to the challenges of product development drops below two, a team will almost surely fail.

*NeMuTec*

NeMuTec's mentor company, Cell Based Delivery (CBD), was founded by former Brown University professor, Robert Valentini. This mentor company worked on using tissue grown from stem cells as a drug delivery system to help in drug treatment in hemophiliacs. They had developed methods to grow both skeletal and cardiac muscle outside the human body, and challenged the student group to find new uses for such ex-vivo grown tissue.

The student team started with nine members at the beginning of the year, but lost one member between semesters. Their original nine members included an electrical engineering graduate student, three engineering undergraduates (mechanical, civil and one unspecialized), two biology undergraduates, a political science undergraduate and a business-sociology undergraduate. All of the engineering undergraduates had taken numerous courses in economics while one of the biology undergraduates was also majoring in public and private sector organizations.

The decision as to selection of the group's CEO came down to a choice between two members: the mechanical engineer and business-sociology major. To decide, the other group members met amongst themselves and had a discussion and vote. In the end, the business sociology major became the CEO and the mechanical engineer became the COO. NeMuTec compartmentalized its team members more than did the other two groups. The two biology majors researched biology issues; the business sociology and political science majors looked at market data; all the design was done by the engineers in the group as non-engineers did not have the requisite knowledge; the financial projections were written up by an engineer who had taken a number of business courses. After the initial decisions, the positions remained defined as they had been for the remainder of the year.

NeMuTec's biggest difficulty was in the complexity of its technology. The engineers on the team struggled in the beginning with defining what they actually had to work with, and what its capabilities were. Once they better understood the technology, the group produced a multitude of ideas. Some members found that deciding among competing application ideas to be one of the most difficult parts of the course; team members became attached to their own idea and took negative comments on these personally.

In the end, NeMuTec decided to develop a drug testing platform for research on contractile diseases. The concept utilizes the traditional 96-well Petri dish fitted with 3-D muscle tissue specimens in each well. The muscle tissue is wrapped around a pressure-sensing silicon balloon, as illustrated in Fig. 4. The aim is to capitalize on the recent trend in drug companies to outsource drug testing. To receive FDA approval for a drug, pharmaceutical companies must prove both safety and efficacy. While preclinical safety testing is done on human cells, preclinical efficacy studies can only be done on animals. By offering human tissue preclinical efficacy testing, NeMuTec predicts that they can save the companies billions of dollars on drugs that won't work within the human metabolic system. They called their product the NeMuSphere$^{TM}$, reflecting the geometry of the tissue platform. Their financial projections showed that the company could have revenues of \$200 million per year by 2007. By the end of first semester, NeMuTec had the basic concept worked out and had ordered the materials necessary to create a prototype. However, they had not yet managed to find a group of drugs on which to focus testing.

There was a feeling that the productivity of the group could have been higher at some key times. Some felt that during the time that some members of the group were stretched very thin, if others had been pushed more they might have been able to accomplish more work on the prototype in the first semester, instead of leaving work-up of the design details until the second semester.

During the second semester, NeMuTec dealt with the details of the design. Design considerations included many issues with materials. The balloon that the muscle was grown around needed to be capable of being finely machined at very small sizes. In addition, it needed to be biologically inert so that it would not react with either the muscle cells or the potential drugs. Additionally they needed to find out if a device exists which could accurately measure the small pressures that the balloon would feel during contractile testing. Most of the design work was performed by the graduate student team member, although some of the basic background research was produced by other members of the technical team. Although the non-technical majors did not contribute to the design, they did make an effort to understand the technology behind it. Like Spectrosity, one of the biggest strengths the group had was the diversity of their members. Many members could contribute in many areas.

NeMuTec found the presentations to potential investors very helpful. They received a great deal of positive feedback about the core idea and the visitors' suggestions helped them create a strong business model.

NeMuTec had a hard time keeping a high level of motivation among all of its members. During the first semester most of the team participated actively. By the middle of the second semester, however, people started to become distracted by other commitments. By the end of the year, only two of the team members were really devoting the required hours to finish the project.

By the end of the school year, Cell Based Delivery closed its doors and its former CEO offered to engage with NeMuTec in a new relationship which is still developing. Two of the student members, the engineering graduate student and a graduating senior (the team's CEO), decided to stay with NeMuTec. The company has since changed its name to Myomics and secured a significant amount of state funding to carry on its efforts and moved off campus into a start-operated incubator setting.

*Anemitech*

Unlike the other student companies, Anemitech's parent was a set of individuals instead of a corporation. Dr. Gregory Jay of Rhode Island Hospital provided the group a patent-pending algorithm, which analyzes the red, green and blue components of digital images of the conjunctiva of the human eye and returns the patient's hemoglobin reading, as illustrated in Fig. 5. The conjunctiva is the mucous membrane located below the lower eyelid. Blood vessels are very near the surface of this tissue. Physicians have long utilized the coloration of this tissue, in a purely visual examination, to assess in a preliminary way whether a patient is anemic. The concept is that a formal analysis of the coloration on a digital image of this tissue should provide a more reliable measure of the hemoglobin content of the blood in the vessels of the conjunctiva. In addition to this basic concept, Dr. Jay suggested that the group look into interfacing the algorithm with a Personal Digital Assistant (PDA), since these platforms are increasingly popular with physicians.

Anemitech was the largest of the three student companies, with ten final members. At the beginning of the first semester the group started with nine different majors: history, east Asian studies, international relations, political science, biology, private & public sector organizations, computer science, chemical engineering and mechanical engineering. Anemitech waited until almost the end of the first semester before deciding on roles for its members. The VP of Marketing and CEO were the most desired jobs. To determine the CEO, the group held a vote. To decide on a VP of Marketing, a number of compromises were involved, as regards assigning different individuals to different tasks. Just as in the other groups, the technical jobs went to technical majors: Chief Technical Officer (computer science major) and VP of Research (chemical engineering major). The group split the role of VP of Marketing into two positions which went to the biology and political science majors. The East Asian studies major decided to become the VP of Sales, with an understanding that Sales would not occur for at least another year so he would be able to work closely with the marketing team. The history major had been working as the liaison between the doctors and the students; he took on the job of Chief Operating Officer. Additionally, the international relations major decided to work on public relations and the private and public sector organizations major became CFO. Although each person had a very specific position, the only time the group really followed the distinctions was in drafting the original business plan. Otherwise there was a reasonable amount of crossover on the business side. As with other groups, the non-technical majors found it difficult to get involved in the technical side because they lacked the necessary skills.

The first hurdle the group faced was in obtaining a copy of the proprietary algorithm. Rhode Island Hospital, the parent institution of Dr. Jay, required signature of a non-disclosure agreement. Signing this agreement was held up for two months in 'ironing out' language that would be acceptable to both parties. Since the algorithm was not available, design was confined to creating an interface on the pda that would accept the algorithm.

The next issue the group faced was compatibility. The original algorithm was based on values determined by the Macintosh-based freeware program, NIH Image. Palm software has a Java interface, but NIH image is not compatible with Java. One of the members of the group found a freeware program called ImageJ which looked like the same program as NIH image for PCs (therefore

Java compatible), however, upon closer inspection it was determined that ImageJ did not have the capabilities necessary to compute the algorithm. The algorithm boiled down to an NIH image macro (small program within NIH image) and ImageJ did not support macros.

Additionally, the algorithm created by the mentor physicians did not yet provide an adequate correlation with the actual hemoglobin values. Originally the group thought that it could change some of the coefficients to create a better curve fit, but in January, after a meeting with the algorithm's creator (an associate of Dr. Jay), the group members decided that an entirely new algorithm was needed. One of the engineers on the team was assigned to head the project of creating the algorithm.

During the second semester, emphasis on prototype development increased. The team brought in a computer science major to help create the required interface. The student roles went through some major evolutions throughout the course. In the beginning of the first semester, the engineers and other technical majors performed most of the scientific research while the liberal arts majors looked at the market. As the semester progressed, some of the students began to cross disciplines. Many of the engineers started to examine market information obtained by the liberal arts majors. Like all startup companies, when something needed to be completed quickly, the entire team worked together to meet deadlines. Technological know-how often helped the marketing team. For example, at the beginning of the second semester, the group put together a marketing brochure written and designed by the marketing team but formatted on the computer by one of the technical team members.

Interaction between the technical and non-technical members was rarely an issue. The technical people learned how to explain the mechanics of the design process in layman's terms and from there the non-technical team members learned what the technical terms meant. Although the personalities of some members were different, the team had great 'chemistry'. Some of this team's spirit came as a result of competition with the other two student teams.

The last part of the second semester involved preparing several fifteen-minute comprehensive company presentations. For Anemitech, the biggest difficulty was convincing potential investors that anemia is a serious problem and that new diagnostic methods would be valuable. The company struggled with the problem in the beginning, and decided to take an 'improved quality of life' approach. The slogan for the product, EYEnemia, changed from 'EYEnemia, diagnosing anemia in the blink of an eye' to 'EYEnemia, improving quality of life in the blink of an eye'.

Anemitech was also a finalist, though not a winner, in the Brown University University New Venture Program which awards $25,000 in cash and services to the first place winner. At the end of the year the group presented its final fifteen-minute presentation to mentor group physicians, along with a business plan and a demonstration of the interface. Over the summer of 2003, two of the group members worked part-time on filing grant proposals and entering business plan competitions. One of the major hurdles faced by this group was access to a good validation data set. The group's mentor provided copious amounts of data that had been taken as an adjunct in other studies. The greatest problem that the group faced was that it did not have direct access to experimental studies that it could control. As a result, algorithm refinement was hampered, because the normal cycle of hypothesis testing and experimentation could not be closed by the group itself. This type of problem may be expected any time groups become involved with products that require testing of human subjects. This is not to say that such projects are not good choices—they are in fact very popular with the students. From the perspective of the average engineering educator, there needs to be recognition of the strict requirements related to any testing on human subjects and how this might represent a significant hurdle to technology development.

Several of the juniors in this group have continued working on this project into their senior year with Dr. Jay. This project continues to have great potential so we are hopeful that this particular project spins-out in the future. An ancillary benefit and unexpected outcome of the course is that one of the course faculty continues to work with Dr. Jay on this project. A piece of his intellectual property developed in his research laboratory can potentially make this technology much more sensitive. Research grant applications have also been submitted. So in addition to students finding great benefit in this course, faculty also does.

## SUMMARY

A technology-based entrepreneurship course can be an educationally rewarding experience for both students and faculty. Providing students with a simulated, but realistic, entrepreneurship experience allows them to gain a greater understanding of what it truly means to be an entrepreneur. This 'real-world' experience helps students decide whether or not a career as a high technology entrepreneur appeals to them.

The technology aspect of the course helps technical students to learn how to apply the concepts learned in the classroom in a market-oriented way. Engineering students gain more confidence in their knowledge base, especially in terms of contemporary problems, and are better equipped for the problems they will face if they choose to pursue a traditional engineering career path. For students in a liberal arts college environment, the course provides the experience of working in a business environment with people of diverse backgrounds. It provides valuable lessons in effective team building. It also introduces all to the many key elements that go into creating a successful business in today's high technology landscape.

For faculty, the course provides a challenging and intellectually rewarding experience. It is enormously demanding of time and commitment. This is not a course that can be developed once and offered from the same syllabus year after year. It is a Dean's or Department Head's dilemma, as it is popular, but very demanding of faculty resources. Those who have been through it will probably later find 'ordinary' courses too slow-paced, by comparison. It is not a course for the junior faculty struggling to start a research career, and not a course for those who do not enjoy working on product development or engineering problems of a more practical nature. But for those who enjoy the demanding, unstructured environment, it is positively invigorating. After all, how many times does a faculty member get to see on post-course evaluation forms the wonderful words, 'best course I have taken at this university,' or statistics where student surveys unanimously indicate it was their best undergraduate course ever. The credit here belongs not to the faculty, but to the unique structure of an experience that engages students, faculty, and industry in a compelling educational experience.

In the future we plan to continue the course. Our initial NSF grant has finished and the Division of Engineering has integrated the course in their regular engineering curriculum. In fact, it is a capstone option to a new university initiative to promote and teach entrepreneurship university-wide. It is a subject of future student requirements to track students who participated in the course over the next 5–10 years to see how they view the experience after being in the professional world for some time, and whether or not those who have taken the course have a higher probably of becoming an entrepreneur than those students with no formal entrepreneurial coursework.

*Acknowledgements*—The authors wish to acknowledge the financial support of the National Science Foundation (EEC-9972938). They also acknowledge a supplement from the NCIIA, under grant 381–00 (which assisted in student travel), and NCIIA grants 488–01 (Handprint), 718–02 (Ferrosity), 749–02 (Conformance Solutions), and 559–01 (Piggyback), which has supported several groups after the course. We also would like to acknowledge the Brown Entrepreneurship program which organizes many entrepreneurship forums and workshops throughout the year, in which many of our students benefit. We acknowledge the time and support of all of our mentors over the past four years; Steven Petterutti (Zebra), Robery Danahy (Zebra), Robert Valentini (CBD), Gregory Jay (RI Hospital), Jason Harry (Afferent), Steve Kleshinski (Afferent), Terry Feeley (LaserFare), Joshua Gutman(Physician), Roman Rondiak (Albany), and Gene Yon (Foxboro). Without their willingness and commitment there would not be a course.

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