The NCIIA: Turning Students into Inventors and Entrepreneurs

Phil Weilerstein, Francisco Ruiz and Michael Gorman

National Collegiate Inventors and Innovators Alliance / Illinois Institute of Technology / University of Virginia

Abstract

Can invention be taught? The pursuit of open-ended commercially focused projects provides opportunities for students to use design and problem solving skills, techniques and tools in a multi-disciplinary team setting. Through this process, students gain the skills, knowledge, confidence and commitment to test their inventive and entrepreneurial skills in the world. This paper provides an overview and profile of two courses developed under a program which provides support for the development of new approaches to engaging students with innovation by providing opportunities for the creation of new products and ventures as part of the educational experience.

The National Collegiate Inventors and Innovators Alliance (NCIIA) is an independent interdisciplinary educational program supported by The Lemelson Foundation to foster and promote the teaching of invention, innovation, and entrepreneurship by facilitating and supporting collaborative learning structures at colleges and universities nationwide. A major focus of the NCIIA has been engineering education. The two undergraduate engineering programs described here illustrate the diversity of paradigms that can successfully be used to introduce students to independent innovation.

The first, is the Illinois Institute of Technology's (IIT) "Invention Center" where engineering projects are carried out in the studio environment typical of a Fine Arts class. Students are coached, rather than lectured, on everything that needs to be done to come up with a successful idea, make a prototype, and develop the legal and business aspects of it. The second, the University of Virginia's Invention and Design course uses a classroom apprenticeship which is created through the use of active learning modules where students are confronted with open-ended problems. In both programs, ideas must be patentable and lead to a working prototype before a semester's end. In addition, students must deliver a patent description and a business plan, and make a formal presentation before judges from industry. These courses provide an effective approach to meeting ABET Criterion 3 outcome requirements by integrating technical and non-technical aspects of applied innovation in an organic way to encourage creativity, self reliance and the emergence of inventive competence. NCIIA grants and resources have supported the development of these courses and the continuation of the most promising of the student projects emerging from them towards commercialization.

I. Introduction

The National Collegiate Inventors and Innovators Alliance (NCIIA) is a unique interdisciplinary educational program. The NCIIA aspires to nurture a new generation of innovators by helping colleges and universities to prepare undergraduate and graduate students to be inventors and entrepreneurs. The NCIIA and its grant fund were created with funding from The Lemelson Foundation, a private non-profit philanthropy, to support educational initiatives in innovation.

The Alliance provides support in the form of grants to faculty and students, services and information for members, and meetings, workshops and other resources designed to assist in the development of new programs focusing on commercially directed innovation. A young and growing program, the NCIIA has close to 100 member institutions. Since its inception in the fall of 1995, it has provided over one and a half million dollars in grants to support 115 classes, programs and student projects at over 70 colleges and universities throughout the country. Approximately one thousand students were involved with E-Team classes and projects during the 1997-98 academic year. The program had its origins in the passionate belief of its benefactors that the health and prosperity of the American economy results in large part from the creativity and ingenuity of American inventors and the unique legal and economic structures that protect and encourage the development and commercial exploitation of their ideas.

The primary mechanism in this effort is the E-Team (the "E" stands for excellence and entrepreneurship). An E-Team is a group of students, faculty and mentoring professionals who together pursue the development of an idea, product or invention, or solve an open ended problem in a way that is likely to result in the licensing of new products or technologies or the startup of entrepreneurial ventures. The E-Team serves as an interdisciplinary bridge crossing over barriers between traditional disciplines (such as engineering, business and liberal arts) and between the business and academic communities. It is intended to serve as a flexible, open model and a source of new ideas rather than a doctrine. The pursuit of solutions to the problem creates a “need” for technical knowledge that informs and enriches the students’ learning experience in other courses while providing the broader intellectual development resulting from working in a collaborative group environment[1].

E-Teams were pioneered at Hampshire College an innovative private liberal arts college in western Massachusetts as part of the Lemelson Program in Invention, Innovation and Creativity. Students participated in courses in which teams of students formed to develop solutions to open-ended real world problems by creating solutions with commercial applications. These E-Teams were given the opportunity to apply for grants to support the development of innovative ideas. The project was highly successful in engaging students in the process of collaborative innovation and teaching about creativity and entrepreneurship. Participation in an E-Team was often a watershed experience in a student's academic career and has led to the development of products and businesses in a variety of areas.

The success of this program led to the creation of the NCIIA in November 1995 as a national alliance to promote and support E-Teams in higher education. In the first three years of its operation, E-Teams have been created at institutions ranging from large universities to small elite colleges. NCIIA grants provide support to classes where E-Teams form in a variety of disciplines including engineering, computer science, business and psychology. Student led teams may also form outside of classes. E-Teams of graduate or undergraduate students can apply for grants of up to $20,000 to pursue the development of their ideas by building prototypes, pursuing patents, writing business plans and doing market research. Brief (less than five page) proposals are accepted from faculty and students at member schools biannually in December and May. Proposals are competitively reviewed by committees of faculty, entrepreneurs and corporate R&D professionals. Grantees are usually funded within 60 days of submission. Allowable expenses include equipment, supplies, travel, technical services, limited faculty stipends and expenses directly related to creating an E-Team program.

II. Learning Engineering as Art at the Illinois Institute of Technology (IIT)

Engineering education is sometimes described as an assembly process[2]. Educational programs have a perfectly structured series of steps (semesters, course sequences with well-polished syllabi) whose mission is to build the students' knowledge, piece by piece, in a repeatable manner. A student's knowledge is being built the way an automobile is built. After all the pieces are put in place by the basic courses, the capstone courses are supposed to make all the connections between them before the product —the new engineer— is delivered to the market. Their knowledge runs quite well for a while with frequent tune-ups (continuing education). Engineers produced in this way, like cars, tend to be inflexible, and become obsolete with time after which they are replaced by newer "models".

When viewing engineering as an art, however, a different paradigm of engineering education emerges. Instead of "assembling" new engineers in a production line, where productivity (maximum knowledge in a minimum amount of time and effort) is the goal, new engineers can rather be "grown" in an organic way. This growth process becomes part of the individual and leads to a long term flexibility and resilience.

Art instructors recognize the need to practice the techniques taught in the courses at the same time as they are being learned. Art students take studio courses from the very beginning of their programs. In these courses, the students work on assignments under the watchful eye of the instructor. A master-apprentice relationship is established, which allows the transmission of a type of knowledge that would be difficult to transmit in a standard course[3]. The sense of whether a certain composition "works" is developed with time, by carefully exposing the students to situations that challenge them to use their developing aesthetic sense. In the same way, engineering students can learn what combinations of physical elements, practical and commercial considerations are conducive to a satisfactory result, so that their designs "work" in a very real sense.

The engineering studio course "Invention and Innovation" was created as part of the new requirement for IIT undergraduates to have at least six semester credit hours of "inter-professional projects". These projects are intended to expand the views of the students beyond their academic major. Our "Invention and Innovation" classes combine technical aspects (a working prototype must be built) with law (a patent must be written), business (through a business plan) and social aspects.

The program has run continuously for three years under funding from the Fund for the Improvement of Post-Secondary Education and the NCIIA. . Class size is small (under ten students), and it has consistently been one of the most popular choices of "inter-professional project" during the prototype phase of this new degree requirement. The idea of the course is to help students become more creative by engaging in actual inventions, their inventions. Each student is expected to come up with a problem and a patentable solution for it: new, useful, and not obvious. Students have individual projects but in a participating "small company" atmosphere. This atmosphere is created at the "Invention Center" where each student has a personal desk, in addition to shared computers for computation, word processing and Internet access and sufficient mechanical prototyping tools.

Having a place for this activity provides a context for the students' creativity that allows them to focus on their projects with an intensity that could not be achieved if they had to go to different laboratories or information sources to piece their ideas together. As they work in this environment, they develop a maturity that enables them to apply these creative skills effectively. The students learn to "turn their creativity on" when they enter the studio class in almost an automatic way [3].

An added benefit of the studio experience is that it helps the students become aware of their need to learn. In the past, this impulse has caused artists to study geometry, human anatomy, and even chemistry. In the same way, struggling with a project that requires knowledge of digital circuits will inspire engineering students to seek out the course where that is taught with an eagerness to find the solution to their problems. Having prior specific questions about the material to be learned is one of the best ways to be motivated about a course and effectively assimilate what is being taught. In this way, a curriculum involving projects like these helps improve the students' performance in their basic disciplinary studies.

Finally, a studio context is a superior way of learning to work in teams. Outstanding industrial teams owe their success to having a "shared space"[4] where engineers can interact with each other and with other professionals. This shared space can be a prototype, a real place, or even a virtual place in a computer network, as long as everyone is able to access it and manipulate it. It is shared by all and any participant can use it as personal property, allowing them to release their creativity on it.

Since its inception in 1995, there have been a number of interesting E-Team projects developed at the IIT Invention Center. Some examples follow illustrating the scope and outcomes often seen with these projects.

(3) Federico Sciammarella's "Alarm for Personal Items" will beep if you walk away from your umbrella, your glasses, or whatever else has been tagged.

(4) Jesus Jimeno's "Child-Proof Senior-Friendly Bottle Cap" is an item that won some attention. Unfortunately, some pharmaceutical companies were developing it at the same time. Rather than feeling bad that someone had beat him to market, it was an indication that his thinking was on the right track.

(5) Priyankar Balekai led a team "Fighting Pollution with Ozone," which won the B.F. Goodrich Collegiate invention award and received an advanced E-Team grant from the NCIIA. The project continues, having involved other students since that time. It is now focused on reducing pollution from small engines.

(6) Jameelah Sharrieff's "Massaging Infant Car Seat" prototype is making the rounds all around the Chicago area. She came up with the idea when her small boy began to cry precisely at the moment when she can least take care of him: driving. The idea is headed towards commercialization

(7) Tony Chivilo's "One-Way Jumper Cables" are also for cars. He is targeting the professional market: those who are called to give a jump to a car in the dark and may, therefore, easily connect the wrong terminals. With his invention, the cables are always connected properly.

Engineering Educators have been aware for a long time of the need to add a creative element to their programs. Many Engineering schools have recently started open-ended project courses that are intended to provide some help in this direction. If the students' creativity is to be cultivated, however, these isolated project courses are insufficient. To summarize, from the experience and perspective gained at IIT's Invention Studio a higher education program whose purpose is to cultivate inventors should have the following characteristics:

(1) It should include a substantial amount of project work. For best results, students should be engaged in projects at all stages of their educational experience.
(2) While engaged in team projects students should maintain a rigorous set of classroom-based courses.
(3) Project activity should be conducted at a centralized location, as opposed to dispersing it among a variety of shops and laboratories. A centralized facility engenders a sense of community among participants and is also helpful in making the projects grow into startup companies.
(4) The students need to be taught not only how to create their devices, but also how to make them a success. This involves sufficient instruction in business, law, design, manufacturing, marketing, etc. for them to be intelligent entrepreneurs and consumers of these professional services.
(5) The artistic angle of Engineering (or "Invention") should be specifically targeted. Thus, the project activity should take the form of studio courses, patterned after those in the Fine Arts.

III. A Course on Invention and Design at the University of Virginia

A very different approach to providing apprenticeship to students engaged in innovation was developed at the University of Virginia (UVA) in the School of Engineering and Aeronautical Sciences. Rather than the physical studio and faculty apprenticeship used at IIT, this course provides a self directed virtual apprenticeship with the innovations of great inventors such as Alexander Graham Bell. A course on Invention and Design based on active learning modules[6] was developed by Mike Gorman, Larry Richards, a psychologist who specialized in design and manufacturing and William T. Scherer, a systems engineer who was an expert at supervising complicated team projects. The Invention and Design course is offered as one of a group of courses that satisfy the upper-level communications, humanities and social sciences requirement for engineering students at the University of Virginia, and as a senior seminar in the Psychology Department.

A major objective of the course is for students to understand and adopt the cognitive processes that guided the creation and interpretation of great inventors, in this case using a module based on the invention of the telephone[7]. Students try to improve on Bell's original telephone design and patent, using similar materials. The purpose of this module is to teach students how to invent: how to keep a notebook, conduct systematic experiments, work in teams, draft a patent application and create a prototype that demonstrates proof-of-concept. As the course evolved, more-and-more scaffolding was added, in the form of additional materials on patents, on writing notebooks, and on other aspects of the invention process. The goal of these materials was to make the students less dependent on apprenticeship with faculty and better able to work on their own in teams, using the scaffolding provided[7]. Students did not have a central studio, and so had to develop portable prototypes and materials.

Students in the course were recruited from juniors and senior undergraduates in a variety of majors at UVA, though the majority (2/3) who attended were from engineering. To accommodate differences in knowledge, background readings were placed on reserve. Expertise was carefully balanced within teams, so that a political science student might be working with an electrical engineer, a chemical engineer and a psychology major.

With NCIIA course development grant support and inspiration gained at an NCIIA conference, the course was modified to require as a deliverable a draft of a real patent, something the very best student teams could go forward with. NCIIA funding included a trip to the patent office, where students worked with Express Search, Inc, to learn how to do proper patent searches. The NCIIA would also fund student teams that intended to continue work beyond a course, provided their goal was a marketable innovation. Therefore, a student team from this course could get a good start on a patent, then apply for funding from the NCIIA to finish the job and take it to market.

Final projects included:

(1) A system that stored the energy from braking a car in flywheels.
(2) A system that would generate and store energy from the motion of waves.
(3) A method that would substitute recycled tires for carbon in certain kinds of filters.
(4) An automobile wheel made of composite materials.

One of the students in the course put together an NCIIA Advanced E-Team project proposal to create a windmill-based system that could be used to regenerate anaerobic soil in places like dredging spoils, where the normal aerobic organisms in the soil can die from lack of oxygen. These portable windmills could save energy over conventional sources of power, and allow the system to be operated in remote locations. A prototype was built, demonstrated at an NCIIA conference held at the Smithsonian Institution, and as of this writing, patent protection is being obtained and planning is underway for initial sales. (For a complete description of the system, see http://128.143.168.25/presentations/nciia/env_stu/aer.html).

Another successful project is a tool that has the potential to help turn students into inventors and entrepreneurs. One of the keys to successful inventing is keeping detailed notes on the invention processes. Bell was particularly good at this[9]. Such notes can play a critical role in disputes over patent priority, and assist an inventor in coming up with new ideas. With support from an NCIIA Advanced E-Team grant, a series of teams of systems engineering students have worked on developing an electronic inventor's notebook (see http://www.hitechsol.com/toolkit) that organizes an inventor's ideas and notes into a form that a patent attorney could readily convert into a patent.

The NCIIA objective of having students focus on projects that have real impact and commercial potential, not just assignments for school, has brought out the best in many of the participants. Students were expert at being students, often doing just what was necessary to get a good grade, and not going above and beyond The project experience has transformed many students into driven, creative professionals.(See Gorman[7] for other examples and a more thorough discussion.)

Support from the NCIIA has added considerable value the program at UVA, well beyond the Invention and Design class. The opportunities for substantial project funding provided by the NCIIA Advanced E-Team grants program are used as an incentive and path for continued work by students who have an invention idea. Furthermore, the E-Team process takes teaching beyond a single class. Gorman continues to work with students after they have been in a course, and often the greatest learning comes at this time, when they have to forge ahead on a project of their own choosing. Although not every group succeeds, everyone learns something from the process of stretching their goals beyond their GPA to considering that they might be able to create a new and marketable product.

IV. Summary

E-Team participants often become very passionate about the work they are doing and report that it was a crucial part of their educational experience. By operating essentially as teams of entrepreneurs, they have the opportunity to develop the confidence and skills necessary to succeed as technical innovators in the real world. They manage a budget, work against a project schedule, deal with recalcitrant suppliers and make decisions, all in a low risk environment. Not all projects succeed, but the process of pursuing a real commercial opportunity provides a transformative educational experience that will have a long-term effect on the way these students see themselves and think about their careers.

These outcomes are in line with those required under ABET Engineering Criteria 2000[10]. ABET Criterion 3 outcome requirements include the ability to apply knowledge of mathematics, science and engineering to formulate and solve problems, function in a multidisciplinary environment and communicate effectively. The pursuit of open-ended, real-world commercially focused E-Team projects provides opportunities for students to acquire and practice these skills by using the design and problem solving skills, techniques and tools that they have acquired in other course work in a multi-disciplinary team setting. The process of going from an idea to a product requires mastery of skills in communication, decision-making, and research. Importantly, this learning takes place as part of a project about which the student has a sense of ownership. Some of the teams succeed in creating a product that will enter the marketplace or start a business venture. But even those whose projects never reach commercialization are far ahead of most of their peers in their preparation for a productive and successful career as innovative and economically productive members of society. Additional information on the NCIIA and the grants program is available at the program website (http://hampshire.edu/nciia) or by contacting the first author.

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PHIL WEILERSTEIN
Phil Weilerstein is the Program Director of the National Collegiate Inventors and Innovators Alliance (NCIIA) at Hampshire College in Amherst, MA. Mr. Weilerstein holds a B.S. from the University of Massachusetts where as a student he was a co-founder of EcoScience Corporation, a biotechnology company. Mr. Weilerstein also consults in the areas of strategic planning and quality management.

FRANCISCO RUIZ
Francisco Ruiz is Associate Professor of Mechanical and Aerospace Engineering and director of the Invention Center at the Illinois Institute of Technology, in Chicago. A native of Spain, he received his Ph.D. from Carnegie Mellon University. Dr. Ruiz's research focus is in the area of Energy, including engines, atomization, alternative fuels, electric vehicles, and refrigeration.

MICHAEL GORMAN
Michael E. Gorman is an Associate Professor in the Division of Technology, Culture and Commerce in the School of Engineering at the University of Virginia in Charlottesville where he teaches about technology and ethics, communications and the psychology of invention and discovery. His research interests include experimental simulations of scientific reasoning and case studies of invention and discovery.