Teaching Innovation and Entrepreneurship Through Design in Inventor’s Studio

Burt L. Swersey
Mechanical, Aerospace, Nuclear Engineering
William Foley
Decision Sciences & Engineering Systems
Rensselaer Polytechnic Institute

Innovation and entrepreneurship are two words that are often put forward as goals for engineering education. Although most of our students will not start new companies upon graduation we can prepare them to act in an entrepreneurial manner within their organizations, i.e., to act as “intrapreneurs.” And if we are successful, they will help to create innovative new products, methods and services that will produce growth in the economy and improve the quality of life.

The following is part of an email message from a recent graduate who was excited about his success as an entrepreneur and inventor in a large company.

“I just wanted to share with you my success in finding a great job. I've been working at [a major medical equipment company] since June. The position I'm in is a perfect fit for me. I'm working on a small team developing a new medical product from the ground up. I jumped in the first week I was here and totally blew my team away. I will have 2 patent applications in soon. I have become very respected in the group and am doing a lot of the design work on the project. My prototyping, drawing and creative problem solving skills really help me a lot here. My day to day work is very similar to the IED/PDI/Inventor’s Studio experience. The fact that I keep a good notebook and am able to come up with and more importantly demonstrate design solutions has helped me be a great success. Everything I learned in your classes puts me at a huge advantage! Thanks!”

The message made our day. But how can we teach engineers to be entrepreneurial in a course on design? At the heart of being entrepreneurial, is the ability to see opportunities that others do not see and create solutions that satisfy that unseen need. We have found that there are three key abilities that can be nurtured in design courses that lead to innovation:

1) Learning to be critical, find the compromises in what exists and identify the unrecognized opportunities that therefore exist.
2) Setting high goals and creating a vision of what would be ideal and then designing something that makes the vision a reality.
3) Using new existing technology, especially microprocessors and sensors, in new combinations, to create new artifacts that address the unrecognized opportunities.

Engineering design has changed. In the 1960’s young engineers were often hired to work on government defense contracts. If an engineer told his boss that he thought that there was a better way to design something, the reply was likely, “you may be right but the Government accepted our RFP and defined the terms of what they wanted. Give them what they contracted for.” Of course there were opportunities to solve unforeseen problems as they arose, but basically, the problem and objectives were clearly defined and the engineers worked to fulfill the terms of the contract. Now engineers are expected to “make it better, faster and cheaper” and it is up to them to define what is needed. One of our graduates related an incident that illustrates the point. He and another young engineer meet with their boss and were told to “make this product better.” As they left their boss, the other engineer said, “But he didn’t tell us what to do.” The first engineer answered, “If our boss knew exactly what needed to be done, he would do it himself. Our job is to decide what needs to be done.”

Problem-Finding and Intrepreneurs

In his book *Opportunities*, Edward De Bono says, “Problem-finding is just as important as problem-solving and much more rare.” He goes on, “We find problem-solving much easier than problem-finding because in our thinking we like to have something to ‘react’ to. We like to have in front of us some information and some desired goal. Then we work to achieve that goal through skilled use of the information.” We believe that it is very important to teach students to be comfortable with both problem-solving and problem finding. Problem-finding is the most basic skill required of intrepreneurs. They must see problems/needs and opportunities that others do not see and then create something that satisfies these unrecognized needs.

Learning to be Critical of What Exists

Henry Petroski teaches us that “form follows failure”. He says, " Every artifact is somewhat wanting in its function, and this is what drives its evolution. Here, then is the central idea: the form of made things is always subject to change in response to their real or perceived shortcomings, their failures to function properly.” But how do we teach students to see these shortcomings when in fact most of us accept what we have? Petroski again provides guidance in the next chapter of this same book, *Inventors as Critics*:

"If the shortcoming of things are what drive their evolution, then inventors must be among technology’s severest critics. They are, and it is the inventor’s unique ability nor only to realize what is wrong with existing artifacts but also to see how such wrongs may be righted in order to provide increasingly more sophisticated gadgets
Petroski quotes Jerome Lemelson, an inventor with over 500 patents:

"I think the way to go about it is to ask yourself these questions: Is this particular function being properly performed? Is it being performed in the best way possible? Are there any problems with it? How can I improve upon it? ... And that’s the name of the game: improving on what’s existing today."

In another of his excellent books, *Invention by Design*[^3], Petroski devotes a chapter to a discussion of the evolution of the paper clip. He discusses the virtues of the Gem paperclip and explains that engineers and inventors did not find it to be perfect. Pertroski lists six flaws with the Gem paperclip. This leads to one of our favorite exercises in class that takes about 15 minutes. We give everyone a paperclip and ask them to tell us what is wrong with it. The instructor lists the results on the board. Students are encouraged to organize their criticism by arranging their findings into categories—performance, ease of use, unanticipated uses, pre-use and post-use issues. And students are encouraged to add new functions that the paperclip should, but does not provide. The list of shortcomings generally runs to 40 items. The exercise serves as an excellent way to start students on the way to becoming inventors by learning to be critics.

**Courage is Required to Turn an Idea into Reality**

There are many examples of inventions and innovations in music and art that were initially rejected by the establishment. Chester Carlson, inventor of xerography, is reputed to have banged on doors of leading companies for 10 years before a small company in Rochester, NY, Haloid Corporation, now known to us as Xerox, had the courage to take a chance with his new photocopier. The story of Carlson and a number of other innovators is told in *The Innovators*.[^4] Carlson’s experience teaches us that creativity is not enough. Successful invention and innovation, especially of truly radical innovations, requires courage and tenacity to convince others of the need that you have seen. But how do we help students develop the necessary courage?

**Support for Innovation**

In his book, *Creating Minds*,[^5] Howard Gardner traces the lives of seven great innovators, including Einstein, Martha Graham, Stravinsky, Freud and Picasso. All of these people shared some common characteristics. One of these was that they all had a support group to give them encouragement when others did not recognize their creativity. Our design course, Inventor’s Studio is designed to provide some of this same support. In addition, it has been shown that individuals can stimulate each other to go beyond their natural comfort zones and propose radical ideas that are out of the mainstream. Students explain their ideas to a receptive cohort, and first of all receive nothing by positive feedback. Daniel Goleman, in his book, *Working with Emotional Intelligence*,[^6] explains “new ideas are fragile and all too easily killed by criticism.” Goleman tells about the efforts one...

[^6]: Working with Emotional Intelligence, D. Goleman 

company made to prevent criticism that comes too early. He quotes Paul Robinson, director of Sandia National Laboratories, “We have a standing rule that whenever someone offers a creative idea, the people who speak up about it first have to be angel’s advocates, people who support and defend it, only then can we hear the inevitable criticisms that otherwise might kill an idea in the bud.” We enforce this same rule in Inventor’s Studio.

“Market-Driven” plus “Technology-Push”

There are two basic approaches to developing new products. In the standard market-driven mode, research is conducted to determine what is needed in the marketplace. Then specifications are written and given to a design team. The technology-push approach starts with a new technology and looks for applications. Students in Inventor’s Studio do both. First they work to understand the market and the present state of the art and criticize what exists in a structured manner against a vision of what would be ideal. The next step is to apply new technology, specifically sensors, microprocessors and actuation, to more closely approach the ideal. Although there are many other technologies that could be employed, we use microprocessors such as the Basic Stamp® and sensors such as accelerometers from Analog Devices®. Every student in the class is required to design a “smart” device, either using Basic Stamp, or for those with no previous experience with microprocessors, LEGO RoboLab®.

Evolution of the Inventor’s Studio Course

In the same way that a new design evolves, this course has evolved. It started out 10 years ago as a course in creativity, which Larry Kagan of the Arts Department and Burt Swersey offered as a short workshop in creativity. It was fun for us and the students enjoyed it and appeared to learn something. However, creativity to what end? New ideas that do not result in creating something real seemed to fall short of the mark. And we all know people with lots of good ideas and who can tell you what should be done, but who never turn any of their ideas into reality.

For the past five years, we have been making problem-finding part of the design assignment in Introduction to Engineering Design (IED) the design course that is taught each semester to the majority of engineering sophomores. For example, instead of specifying that they need to design and build something to sweep the floors of an auditorium, we asked them to design something that would “improve the cleanliness of the large lecture hall where the class is held.” By the end of the semester, students had designed and built a wide range to artifacts; improved sweepers for use after classes were over, automatic recycling devices that reduced the amount of paper and bottles that had to be collected, and systems that maintained the cleanliness of the room all day long!

Inventor’s Studio was started as a follow on course to IED so that students could choose
to continue on the projects that they started in IED. Initial funding for course support came from the NCIIA, National Collegiate Inventor’s and Innovator’s Alliance. And NCIIA has funded a number of the individual projects, allowing for the filing of patents and further development. An example of a project that started in IED and continued in Inventor’s Studio, is the development of a Double Dutch rope jump machine. One patent has issued on the original design and a second patent is pending.

Ten Suggestions for Teaching Engineers to Invent:

1. Prepare the students by coordinating the course with prerequisites that cover topics such as the design process, using a design notebook and team skills.
2. Insist on designs that are innovative, provide significant benefits to users, combine new technology in unique ways, do not require extensive research and can be done in one semester.
3. Teach students a structured design method.12,13
4. Provide exercises of structured criticism. “Form follows failure.” Designs must evolve. Don’t let them stop with their first idea.
5. Combine market driven and technology push. Focus on making products “smart”. This is highly leveraged and builds their confidence that they can learn to apply new material on their own. Introduce technology such as Analog Devices accelerometer and Basic Stamp.
6. Encourage passion, commitment, hard work. Allow students to find their own opportunities. Share successes in a studio setting. Set up a system so students can share potential future royalties.
7. Provide templates to guide what is expected. Students must show the feasibility of their concepts: technical, cost, ability to patent.
8. Insist on hands on work such as mockups. Everyone must design and build a simple electronics device. Each team member must take responsibility for a specific part of the project. Everyone must perform patent searches and write part of a patent.
9. Individual design notebooks with complete documentation are required and graded. An “A” grade requires an “A” notebook.
10. Enlist the help of a great electronics T.A.

Conclusion

Innovative engineers are needed now more than ever to meet the challenges of the global economy. Design courses can play an important role in teaching innovation and entrepreneurship.

Acknowledgments

Funding for Inventor’s Studio has been provided by National Collegiate Inventors & Innovators Alliance (NCIIA), The Coleman Foundation, Lutron Corporation and Ted
Dale of Golden, CO. Phil Weilerstein Director of NCIIA has been an invaluable supporter. Special thanks to our undergraduate T.A., Travis Bashaw. His dedication and intelligence will be hard to duplicate. We also appreciate greatly the help of Lee Odell of the Language, Literature and Communication Department, for his assistance in teaching the students to make effective presentations and write clear reports. And this course would not have been possible without the support of the administration of the Institute and the long time support and advice of Gary Gabriele, Larry Kagan and Arthur J. Swersey of Yale University.

Bibliography

10. Gibney, Kate March 1998. *Awakening Creativity* ASEE Prism
11. NCIIA, www.nciiia.org

BURT L. SWERSEY, Lecturer, BSME degree from Cornell University. He has been teaching design courses at Rensselaer for the past 12 years. Prior to that, he was president and founder of several companies in the medical equipment field. He holds 12 US Patents.

WILLIAM FOLEY, Clinical Associate Professor, holds a Ph.D and a MS in Operations Research and Statistics and a M.Eng. in Industrial and Management Engineering from Rensselaer in addition to a BSME from the University of Connecticut. He has been involved in teaching engineering design for the past 14 years at both the sophomore and senior level.