Learning Engineering as Art: An Invention Center*

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This article describes a class where engineering students develop potentially patentable commercial products in a studio setting. Students work on two individual projects, with prototypes, patent description, and a small business plan within one semester. The first long-term survey of participating students indicated that the greatest impact of this class was on their understanding of real-world situations, and their ability to come up with creative ideas. Some positive commercialization results have occurred with nearly one fourth of the students participating. The emphasis of the article is on the pedagogical methods involved in this kind of course, although some assessment results are also included.

INTRODUCTION

THE WORD 'engineering' comes from 'engine,' which derives from the Latin *ingenium*, that is, a product of ingenuity. Engineering combines a deep scientific knowledge with creative drive. The engineer's goal is to meet human needs through things that make life easier, safer, etc., and attempts to do so by applying disciplinary knowledge in the same way a painter would use colors to create a painting. Under this perspective, engineering can be ranked among the arts.

Today's engineering education is sometimes described as an assembly process [1] where programs are structured into a series of steps (semesters, and 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 usually built the way an automobile is built: after the basic courses have put all the necessary parts in place, capstone courses are introduced to make all the connections between them, and then the product—the new engineer—is ready for the market. This modular approach is very different from the way fine arts training takes place, and leads to engineers lacking a creative approach to problem solving. An objective (though sometimes scathing) review of this problem can be found in the articles and books by C. L. Dym, of which reference [2] is perhaps the most accessible to the reader. Among many other voices, Schrader [3] expressed the opinion of many in this field, that the current engineering curriculum needs a major revision before it can turn out creative individuals.

When viewing engineering as an art, however, a different paradigm of engineering education emerges. Art instructors recognize the students' need to immediately practice the techniques they learn in their courses, and this is why art students take studio courses from the very beginning of their programs. In these courses, they work on assignments under the watchful eye of the instructor, establishing a master-apprentice relationship that allows the transmission of a knowledge that would be difficult to transmit in a regular course [4]. This knowledge about the 'artistic side' of their profession is also useful to engineers. Navin [5] discussed a few years ago how the educational method of fine arts and architecture should be used in civil engineering. Similar concepts have been expressed by others; the reader is invited to look, for instance, at Wengenroth [6]. A good case for enhancing the role of the professor as coach instead of mere transmitter of knowledge was made by Tribus [7].

An added benefit of the studio experience is that it makes students aware of their need to learn the techniques in order to obtain satisfactory results. Having prior specific questions about the material to be learned is one of the best ways to be motivated and to actually assimilate what is being taught. A well-crafted studio should encourage students to become more interested in their discipline-specific courses.

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' [8] where engineers can interact with each other and with other professionals. This shared space can be a real place, a prototype, or even a virtual place residing within a computer network, as long as everyone is able to access it and manipulate it. A studio like the one presented in this article works as a shared space for the creativity of the students, who are then able to interact and at the same time make their own personal contributions.

SIMILAR PROGRAMS

In the early 1980s, the US Government provided funding for four new open-ended engineering programs: at Harvey-Mudd, Evergreen College, Worcester Polytechnic Institute (WPI), and the Illinois Institute of Technology (IIT). In these programs, the students were actively engaged in a project and learned the science necessary to carry them out, as they needed it. The experience was that these programs took considerably more resources than conventional classroom-based programs. They also required students to show a great deal of maturity and responsibility in their studies. The WPI program, a total commitment of the entire school, developed into a new philosophy of education and it has continued inspiring a uniquely flexible program of studies. The Harvey-Mudd program also developed into a unique sequence that still exists.

MIT has also had a special experience for upperclassmen since the 1980s, called 'New Products Program,' where students have a special lab, similar to the famous MIT 'Media Lab'. Students form sizable teams, with up to fifteen members each, and communicate among themselves and with the instructor electronically. The New Products Program, which has been richly endowed since its foundation, has run very well. Their experience can be successfully translated to other schools, provided their industrial support base can somehow be replicated.

The concept of studios for engineering is not new. As far back as 1989, Western New England College had a class just like this, which was used as a capstone to a program combining engineering with liberal arts [9]. They found that creativity can indeed be taught to a large extent, if the environment is conducive to it and the students have been encouraged to think in modes different from the usual ones in their majors.

Among fairly recent complete undergraduate programs on creativity, those sponsored by the Lemelson Foundation and the National Collegiate Inventors and Innovators Alliance (NCIIA) deserve to be mentioned. A notable inventor, the late Jerome Lemelson, created these institutions in order to foster creativity and entrepreneurship in schools. The first of such programs is the 'Invention, Innovation, and Creativity' of Hampshire College, established in 1994. Students holding Lemelson fellowships at Hampshire College have a personalized program of studies—as do all students at this small liberal arts college—involving a series of special courses on computer application development, multimedia publishing, 3D design, film and video workshop, optics, human locomotion, and river geology, to name a few.

Another program funded by the Lemelson Foundation runs at the University of Nevada-Reno. Senior students in electrical engineering form 'companies' competing for resources in one of their capstone courses, coordinated by Prof. John Kleppe [10, 11]. Each 'company' has a large number of students with different ranks and functions. Some of the projects have led to actual patents and are approaching the commercial stage, for instance: automatic Venetian blinds, a system to rent cars via cellular communications, and others. The model followed in this class is particularly appropriate for introducing real-world concepts into a large senior capstone course. This program has grown into the Lemelson Center for Entrepreneurship of the University of Nevada-Reno, which was also funded by the Lemelson Foundation.

Still more recently, a great number of educational programs have started which combine engineering design with entrepreneurship and even some artistic component, some with NCIIA funding, like those described by Niku [12] and Carlson and Sullivan [13], but the great majority were developed with the university's own resources, like those at the U of N Texas [14], RPI [15], AZ State [16], and UVA [17].

INVENTION AND INNOVATION PROJECT

From the foregoing considerations and the experience of many years (at IIT and elsewhere), the author synthesized the main parameters of a higher education program whose purpose would be to cultivate creative technical majors. The basic philosophy of this approach was almost exactly echoed by the F. W. Olin Foundation, in their 1996 gift of $200 million to establish a new kind of technical college [18], which is now in its start-up phase. The model is based on the following premises:

- There should be a substantial amount of project work. For best results, students should be engaged in projects at all stages in their curriculum.
- At the same time, students should maintain a rigorous set of classroom-based courses incorporating the latest educational techniques.
- It is helpful to conduct the project activity at a centralized location, as opposed to dispersing it among a variety of shops and laboratories. A centralized facility is also helpful in making the projects grow into startup companies.
- Students need to be taught not only how to create their devices, but also how to make them a success. This involves a sufficient knowledge of business, law, design, manufacturing, marketing, etc., so they can be intelligent consumers of these professional services.
- The artistic angle of engineering (invention) should be specifically targeted. Thus, the project activity should take the form of studio courses patterned after those in the fine arts.

It is not necessary, however, to change everything in an established curriculum in order to meet these criteria. It is enough to add the missing

components and supply an experience that provides cohesiveness to the whole. In addition, fully refurbishing a curriculum is expensive in terms of dollars, faculty time and what could be described as academic 'political capital.' The approach we followed was to simply add a course that could be taken multiple times by any student. This course was called 'Invention and Innovation Project', and is still in existence at IIT, under a slightly different name. A summary syllabus is included in Appendix A.

The course has run under funding from the Fund for the Improvement of Post-Secondary Education (better known as FIPSE, a program of the US Department of Education) and the NCIIA, from January 1996 until this day. It is open to all IIT students, sophomores to graduate, in all departments (since it has no pre-requisites), but class size is normally limited to a maximum of fifteen students. Most students receive three semester credit hours under the 'interprofessional projects' category, which since 1999 is a six-credit requirement for all IIT undergraduates. In this course, students are expected to make two prototypes, write two business plans, an internal proposal, and a patent application, all within one fifteen-week semester. The grades depend on the quality of all these deliverables, as judged by the instructor and other outside judges. The components of the course are:

- the studio setting;
- a warm-up project at the beginning of the semester, followed by the main project;
- frequent student presentations, with lively feedback provided by everybody present;
- a demanding schedule of reports;
- working prototypes.
- Invited seminar speakers
- Funding available for prototype construction and other things

The following sections describe in more detail these components while trying to transmit what has been learned in their implementation, what the potential pitfalls are and what to watch out for in trying to reproduce the program elsewhere. More details can be obtained at the official IIT Invention Center Web site [19] and in reference [20].

The studio setting

The class takes place in a special classroom where the students know they are supposed to be creative. This works much better if the room is dedicated to this purpose, since the presence of other students doing something else during studio time is especially harmful to the studio atmosphere. The room does not have to be very large (a 24 × 48 ft space is just right for fifteen students) but it must have sufficient space for individual desks, a prototyping area, and a computing area, all within view of each other.

In order to save in prototype construction costs, it is best if the students themselves can develop their own prototypes. The room contains a small machine shop equipped with a metal lathe, a mill, a tabletop band saw, a drill press, a sander, and a variety of hand tools. The few computers are used for collecting information, doing patent searches, writing documents, and preparing professional-looking presentations.

During the studio periods, the students exchange information on their projects, with the instructor acting as facilitator. The role of the instructor goes beyond this, however. He or she must make sure that each student is on track and that every part of the project (technical, business-related, and legal) is getting enough attention. In addition, the instructor is responsible for supplying an experienced view on what is likely to be important for each of the projects. This is done by direct private feedback to each student but also by way of mini-lectures, delivered every time the class as a whole has reached a point where a new element must be considered. For example, when almost every student has a certain idea of the details of his/her project, it is a good time to explain how to search for prior art in the patent literature.

By comparing their own performance with that of the others, students are able to gage the shortcomings of their own work and get insights into how to overcome them. Of course, not all projects are exactly comparable: some are easier to prototype, others are easier to concretize from the business viewpoint, and others are intrinsically more appealing and easier to present in public. Therefore, the instructor must use his or her discretion to determine whether any given project is truly behind schedule and in what way.

Projects

The first four weeks of the semester are devoted to developing a quick invention, with a report and a prototype due at the end. We have used two kinds of assignments:

1. A device to help the handicapped or the elderly.
2. A toy or household item to be *sold* at the store for $15 or less.

At the end of these four weeks, the students have sampled everything they will have to use in their main project, and have made all the obvious mistakes already (such as not giving themselves enough time for prototype development). In this way, they are spared unpleasant surprises with their main projects, without having had to 'waste' too much time. Developing an invention is not a leisurely activity: it can soak up all their time easily. It should, therefore—and this is the message we try to get through—be given equal status with their other classes.

On some occasions, and only at the request of students who insisted that they had a very clear idea of what their main project was going to be and that they needed the whole semester to develop it, we allowed them to start working directly on the main project, bypassing the four-week warm-up

project. Our experience has been negative in all of these cases: those students ended up committing the 'obvious mistakes' mentioned above in their main projects, while those who had done the warm-up project fared considerably better even though they supposedly had less time for their main projects.

The rest of the semester is devoted to the main project, which is totally of the students' choosing, with only a few restrictions:

- It must be patentable, at least potentially. Therefore, it must consist of a method, device, or composition of matter that is new, useful, and not obvious.
- It must be simple enough so a working prototype can be demonstrated by the end of the semester.
- It must be able to make money for investors. If it is something that would likely be marketed at a loss, the students must clearly identify the sources of sponsorship and why they should be interested in the project.

Presentations

The class runs under the following overall assumption: 'We are all part of the same small corporation trying to come up with new products.' This 'corporation' has a staff meeting every week, and every 'employee' must be present and tell the others about the status of his or her project. At the meeting, he or she should be ready to collect all the feedback that the other employees are going to provide. The only real difficulty in running these meetings has been making sure that they are brief: it is frequent for students to be carried away with enthusiasm and spend all the class time giving feedback to one another. A consequence of this is that the class size (or, at least, the meeting size) must be kept within bounds. Meetings run well with up to fifteen students; on the other hand, if there are too few students present—and this can happen easily when the total class is less than ten students and there are exams in other classes—it may become difficult to get the right atmosphere for the meeting. There should be at least three or four students for the meeting to be fruitful.

In these weekly meetings, the students brainstorm about the other students' ideas, and in so doing they are coming up with new solutions for their own projects. We have found that this informal sort of brainstorming works remarkably well in class, perhaps because it steps over the self-consciousness barrier that many feel when the idea being discussed is their own. On occasion, we use more formal brainstorming methods and a kind of subconscious idea development like that described by Hawlader and Poo [21].

In addition to the weekly presentations, the students must make two formal presentations in front of outsiders, summarizing their projects into professionally prepared visual aids. These presentations are made as to a group of investors who are considering licensing their inventions to make a profit from them. The students must demonstrate that their ideas are patentable (new, useful and non-obvious), and that they will turn a profit when implemented commercially. In order to safeguard the students' intellectual property rights, at the beginning of the session and of every presentation an announcement is made to the audience that the session does not constitute public disclosure and that those attending must hold what they hear in confidence. If some students do not want to present to outsiders, then they can do so privately to the instructor. So far, no legal problems have arisen from this practice.

Schedule

Engineering students are used to a lot of pressure. They often measure the importance of a course by the amount of work they have to put into it, so that the instructor who reduces the workload in his course soon sees students dropping out because they get busy early on with other courses that are competing for their time. Naturally, a course run under a studio model is a prime candidate for skipping attendance and procrastination, when faced with deadlines in required courses. To prevent this, the grades in our course depend on three fairly lengthy reports (the last one having two distinct parts) and two formal presentations to outsiders. Moreover, their prototypes *must* work or the students lose most of their grade.

The first report is patterned as an offer for licensing to a corporation. The essential points to be covered are:

1. What kind of product it is, the problem it solves and what is currently used by consumers for that purpose.
2. Any similar products that may be found in the market and the patent literature, and a critique of their strengths and weaknesses.
3. A full description of the invention and how it operates.
4. Estimated production costs and sales income.
5. Viability and size of the market.

This report is usually about ten pages long, including graphs and figures. The final report covers essentially the same items, for the main project, but it is structured differently: instead of a single document, the final report comprises two separate documents, each of which is ten to fifteen pages long:

1. A patent application containing all the strictly technical data. It must have the same format as a US patent, including a 'claims' part (the students have previously attended a lecture on this subject).
2. A business plan containing the financial and marketing information necessary for introducing the product into the market. It is to be written in a less formal, more dynamic style than the patent. Its format is that of a typical

business plan, comprising an executive summary, product and market description and strategy, income and expense projections, and appendices.

There are a few periods in a one-semester project where adequate coaching is essential. The most critical is somewhere around mid-semester, when the students, exhausted from their first projects and a barrage of midterm exams in other courses, realize that they still have to find a good project for the class, and that time is running short. It is easy for them to become discouraged at this point. We did not shape the course so this tough period is eliminated, however; instead, we prepare the students for it by telling them that it will likely come but that it is a normal component of every creative project. In any case, the instructor usually has a few project suggestions prepared beforehand for those students who have a particularly hard time overcoming this crisis.

Prototypes

Demanding that each student present a working prototype by the end of each project is not a trivial requirement but is, indeed, quite essential. There are several reasons for this:

- Without prototypes, ideas remain as theoretical constructs. It is not possible to really know whether a certain design would work.
- It is very important to be able to 'see' the idea incarnated in something material (especially for students). It is hard to generate enthusiasm for something that is merely on paper.
- One learns a great deal from a prototype: what works, what doesn't work, and what it would cost to turn the invention into a product.
- A prototype is the best tool for marketing research: it is often enough to ask people how much they would be willing to pay for it.
- From the point of view of presentations, a prototype is the best illustration.
- Making prototypes is one more 'hat' the student has to wear—an important one for an engineer.

A budget is essential for prototypes, equipment, and expert help. If the students' inventions are to have any chance of being successfully developed, it is important to 'reduce them to practice' in hardware. Many patented inventions come to nothing because, when built, defects are discovered that still need a great deal of work. Without the construction of prototypes the invention would be reduced to a simple paper exercise. Moreover, dealing with a prototype is especially useful for students, since they typically do not start out having a good feel for how certain components behave in practice. Prototype development also forces students to contact suppliers and developers outside the university, which adds a dimension of reality that other school projects lack.

Seminar speakers

The bi-weekly seminars, which last for about an hour, deal with real world issues such as: how to get a company started, what to do about patenting an idea, how to come up with ideas when they refuse to come, how to convince company executives, etc. The specific topics change somewhat every term, depending on the particular speakers. While we have had no problems recruiting seminar speakers, scheduling the seminars so they happen at the point in the course that is most beneficial to the projects has been more challenging. Speakers usually volunteer to come without an honorarium, but their time availability tends to be problematic.

Budget

A budget of $200 per student seems to work well for one-semester projects, with additional funding available for special cases. The actual expenditures rarely come near the budgeted limit; usually they are less than one fourth of the budgeted amount.

Instructional cost is the biggest expense, especially for small class sizes, but the problem is not unique to this type of class: it is the same for any laboratory class. The real difficulty is finding instructors willing to run a class like this. So far, the Invention and Innovation class has run with just one permanent instructor (the author of this article), with others called in from time to time for lectures on patents, technical information, search strategies, idea generation techniques, etc. The background necessary to run a studio class is rather unconventional: knowledge of product development, patents, marketing, etc., as well as familiarity with a coaching (rather than lecturing) style. It is by no means necessary for the instructors to be licensed professional engineers, but this may be appropriate in some cases since this often signifies some level of industrial experience.

Well-trained instructors may be the most difficult element to obtain by any school trying to replicate this program. It is assumed, however, that a focused faculty development effort would be able to overcome this problem, since the concepts to be transmitted by the would-be instructors are quite simple.

SOME HISTORY, SOME PROJECTS

'Invention and Innovation Project' has run almost every semester since Fall 1995. In this time, it has evolved from the original concept in several ways:

- It has become obvious that engineering students do not feel comfortable with a full studio environment (as is normal in architecture, for instance). They prefer to meet for short periods of time and then be free to pursue their work elsewhere. Therefore, we have retained the Invention Center as a resource while not obliging anyone to spend a predetermined amount of time there.

- We started bringing in speakers for a biweekly seminar. Since these seminars have been adopted by our school's 'interprofessional project' academic requirement as a whole, we have discontinued organizing them. Our students now go once a week to the seminar, and once a week to our project meeting.
- We used to allow those students who had a clear project idea to start working on it right away. After the experience, we are requiring all students to 'waste' the first four weeks doing a warm-up project.
- It is now a required course for all students participating in our Entrepreneurship Fellows program which, unlike many such programs elsewhere, is based in our Engineering College.

A number of students have already had taken some steps towards a possible commercialization of their projects. While this is certainly beyond the expectations of a one-semester class, it is reassuring to see some of that happening. It is, more than anything, a witness to the interest and personal involvement of the students in their projects. Some stories follow, and still more are summarized in Appendix B:

- M. K. (junior, ME) developed a portable ladder for hunters. Apparently, the hunters' ladders found in the market are rather bulky and easy to spot by game. The current alternative to a ladder is to screw metal steps into the tree itself, which takes time and effort and causes damage to the tree. He demonstrated a prototype weighing less than twenty pounds but able to support more than three hundred pounds. His ladder reaches up to fifteen feet and can be set up in three minutes. It lies flat against the tree, so animals find it tough to spot. He has targeted a well-defined market and knows how to advertise his product. After a second, more refined prototype, he only needs (so he says) to get a patent and start making and selling the ladders. A conservative sales potential exists for more than twenty thousand units a year.
- J. S. (senior, EE) put together a car infant seat that cuddles the child by means of strategically placed motors. The feature adds less than twenty dollars to the cost of a standard child seat. Like in massage pads for adults, the 'massage' pattern can be varied according to several programs. Testing has proved that her invention is very effective in soothing problem infants, both in and out of the car. She has now graduated from IIT but intends to pursue a patent and commercialize her idea. She has identified some ways the product can be made known for a minimal additional cost.
- W. K. (senior, Manufacturing) has a machine snubber that has already been patented and is about to enter production. The most delicate point of this project was when the company where he works (as a mere draftsman) insisted that they were to own anything invented by him.

As a result of his negotiations, the project could not be presented along with the others at the end of the course (except privately to the instructor) but he got something out of it: a promotion and a pay raise.

We can finish this section with J. C.'s (graduate, ME) ozone generator project who started to develop a device for an automotive competition, but John's team went on to demonstrate that a simple ozone generator was able to reduce exhaust emissions under a variety of conditions. The project led to a substantial grant from the NCIIA and the B.F. Goodrich Invention Award, at the Inventors' Hall of Fame.

ASSESSMENT

One of the most difficult tasks in this project has been its assessment, since its primary goal was to instill an attitude and a character trait that would enhance the students' creativity and their ability to make it out on their own. Results in these areas can only be seen after a long time. The education literature presents only a few attempts to measure the impact of educational programs on creativity in the short term. For instance, Wilde [22] conducted pre- and post-program surveys on faculty taking a creativity workshop and found a shift toward more 'creative' learning patterns in a synthetic profile based on the Myers-Briggs learning style test. On the other hand, Larson et al. [23], performed a similar test on students, along with two other creativity-measuring instruments, leading to inconclusive results. These results, among other considerations, led us to undertake a simple, targeted, long-term survey to complement the assessment based on the (normally excellent) coursework delivered by the students.

Still, given that the projects are very applied and create a keen personal interest in the students, a number of early signs of something good happening have already been observed. A number of students have already taken steps towards the commercialization of their inventions. This has occurred for nearly one-fourth of the students involved. Anecdotal as they must necessarily be at this point, these personal experiences can be of interest to the reader (see Appendix B to see a summary of a few of these).

Some recent hard data, albeit limited in scope, are already available. A multi-question survey was prepared in 2000, in order to obtain the students' perceptions on what they got out the course, in many cases years after they took it. The questions were written in an agree/not agree format, with the lowest agreement having a value of 1, the highest a value of 5, and the neutral value being 3. We received responses from approximately one-third of the students polled. The questions are shown on Table 1.

The average results are also shown in Table 1.

Table 1. Survey and summary results

Questions	average	|avg-3|/std
A: I am more creative person because I took the Invention Project class	3.69	0.79
B: The class didn't teach me anything worthwhile about the real world.	1.81	1.30
C: I'm more inclined now to start my own business that I would be otherwise.	3.50	0.46
D: I feel more confident talking with people with different educational backgrounds.	3.50	0.52
E: I don't know much about patents.	1.88	1.40
F: I became pretty good at public speaking.	3.50	0.48
G: I am eager to get criticism from others, and always make good use of it.	4.19	1.13
H: I still get baffled when I get negative, irrelevant, or plain stupid criticism.	1.94	0.95
J: I understand how my boss thinks.	3.31	0.31
K: When I think about a project, I always think first about how useful it can be.	4.25	1.34
L: My problem now is that I have too many ideas.	3.59	0.45
M: My problem is that my ideas are unfeasible or impractical.	2.06	1.63
N: People think I am kind of eccentric	3.25	0.19
O: Now I write down in detail any idea that seems good.	3.38	0.28
P: I come up with ideas in the strangest places and situations.	4.13	2.25
R: People think I am rather narrow-minded.	1.69	1.86
S: Politically, I have become more conservative.	2.46	0.43
T: I have developed an interest for traveling and foreign languages.	4.23	1.22
U: I don't read things outside my field.	1.69	1.29
V: My resume is straightforward: nothing unusual in it.	2.69	0.27
W: A lot of times, I'm kind of unfocused.	2.75	0.20
X: My friends think I'm rather childish at times.	3.06	0.05
Y: I don't appreciate classical music.	2.31	0.46
Z: I've gotten better at remembering and telling jokes.	2.31	0.73

The first numerical column in Table 1 has the average response, and the second shows the average deviation from the neutral value of 3, divided by the standard deviation of the responses, for each question.

Questions M, P, and R showed average responses (in agree/disagree format) more than 1.5 standard deviations away from the neutral value, thus approaching or surpassing the Student-t criterion for statistical significance. The data also showed that a majority of respondents responded at either extreme of the scale in questions B,G,H,K,T, and U (also in Y, with respondents about evenly divided between the two extremes). Most of these are the same as the questions where the average opinion was more than one standard deviation away from the neutral value.

Based on these responses, it is safe to assert that some trends are emerging in the long-term students' perceptions of what the course did for them:

1. They have a better sense of how the real world actually works and their ideas are practical.
2. They come up with ideas under unexpected conditions.
3. They have become more broad-minded.

If credence is also lent to responses that show less statistical significance, one could also say that the students have the perception that the course has made them better able to accept criticism and profit from it and that they have learned a fair amount about patents.

Even with the caveat that this survey collects perception rather than reality, the results are showing (pending a more comprehensive long-term study, to be carried out in a few more years) that the class is having a positive impact. This is exactly the opinion universally expressed by the judges attending the formal class presentations: in some cases, they are so taken by the projects that they have gone out of their way to find them a venue for commercialization. If the long-term impact is in reality as strong as it appears from this survey and the judges' comments, we hope that our program will be extensively adapted for use in many schools.

CONCLUSIONS

1. Students can learn about how the real world functions by engaging in a studio-based project course in which they develop their own ideas.
2. The teaching style of such a course is closer to that of a fine arts or architecture program, but it can be easily undertaken by traditional engineering faculty members.
3. Students going through the experience report a broadening of their outlook, a growth in their ability to come up with ideas easily, and a better understanding of what is practical.

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APPENDIX A: COURSE SYLLABUS

IPRO-x97 Invention and Innovation Project

- three credit hours, Spring-2001
- place: interim IIT Invention Center: 020-E1
- times: Thursdays 3:155:00, other days TBA

Optional textbooks

All of these texts can be found in regular or online bookstores:

- K. Hanks and J. Parry, *Wake up Your Creative Genius*, Crisp Publications, 1991.
- D. Pressman, *Patent it Yourself*, 7th ed., Nolo Press, 1998.
- M. Josephson, *Edison, a Biography*, Wiley, 1992.

Introduction

This is an Inter-Professional Project course, which can be taken by sophomores, juniors, seniors and graduates in pretty much every major. Its purpose is to teach students about Invention by actually engaging in Invention and Innovation . The course is structured both as a lecture and as a lab: it is a 'studio' course for tech types. We will learn 'left-brained' concepts about patents, marketing, new technologies, and more, while using 'right brain' thinking processes all the time. Engineering is one of the Arts, and is treated as such in this class.

We have a fine—though small—facility to do all this: the Invention Center/SAE Lab (020-E1), which has a prototyping facility. Your own workspaces will be located in a nearby room (036). Access is possible

around the clock. We have a small budget for parts, through the graciousness of the IPRO office. Purchases should be approved by the instructor.

The goal is to end the semester with some patentable technology that can be put into the field with little additional development.

Course procedures

Students are expected to attend the IPRO seminar on Tuesdays at 3:15. What follows is about the Thursday meetings.

The first part of each meeting is devoted to presentations: by students, the instructor and guests. Every student is expected to be able to make a short, informal presentation with a minute's notice.

It is very important for all the students to be present during the meeting times, since the main instruction mode is by one-on-one hands-on advising. You may spend additional time at the Invention Center as well.

The grade will be based on the following:

- Working prototypes: 35%
- Presentations and reports: 45%
- Inventor's notebook: 20%

In more detail:

- Prototype #1: 10% of the total grade.
- Prototype #2: 25%
- Report for project #1 and presentation: 10%
- Proposal for project #2 and presentation: 10%
- Final report for project #2 and presentation: 25%
- Notebook: turn it in at different times in the course.

Final letter grades will be assigned according to the following absolute scale:

- A: 80% to full score
- B: 65% to 80%
- C: 50% to 65%
- D: 35% to 50%
- E: less than 35% of full score.

This is what is expected in each of the items which make up the grade:

- Prototypes 1 and 2: they must work as described in the reports or, if operation can only be demonstrated with great expenditure or time investment, they at least must show that the idea can work. Mock-ups just showing the outside look of the product are not sufficient.
- Report on project #1: must describe the idea to a potential investor. Therefore, it should equally avoid technical jargon and unsupported claims, while highlighting the advantages of the idea before its competition. It should illustrate how the idea is to be carried into practice and how it will be commercialized, with as much detail as possible. If the prototype has been evaluated by potential clients, mention what you learned from that.
- Proposal for project #2: describe your idea to somebody who can give you funds to work on it. Highlight its advantages and its potential. Mention the market impact it might have. A good guideline is to follow the SBIR proposal format (available from the Internet).
- Report on project #2. This report should have two parts. Part 1 is a technical description of the idea as it would appear in a US utility patent. Follow that format as closely as possible, including claims. Part 2 is a business and marketing plan, where all the business and legal considerations are collected (they don't belong in a patent). Like in report #1, the idea is to show a potential investor how your invention will make money. Calculating cash flows for a hypothetical venture with some accuracy is a plus. Explain the target market and how your idea can be most successfully launched.
- Notebook: keep a record of your ideas in a bound notebook. This notebook should contain all thoughts, calculations, designs, musings, feedback, etc., about your idea. Date every entry and do not leave large empty spaces. Write in ink only. Turn it to me from time to time, and I will witness it, by impressing my signature.

In all reports, it is a good idea to describe your idea as it will be carried out in practice, not as embodied in the prototypes. The prototypes are to be used to perfect your invention, and as illustrations of the idea. They may look very different from the product you envision, if necessary.

As in all IIT courses, all students are expected to abide by the ethical standards of the IIT Policy on Academic Honesty. Intellectual property will be handled differently whether the project is funded by sponsors or not. The IIT Intellectual Property policy applies.

Important deadlines

- Late February: Presentations for project #1. Report and prototype due.
- Late March: Presentations to propose project #2. Proposal due.
- Last week of classes: Final presentations for project #2. Report (2 parts) and prototype; there will be a team of judges present at this formal presentation.

These are limit dates; if you are done sooner, you may make your presentation earlier and be done with it.

Project topics

- Project #1(four-week warm-up): You have two options:
  1. A toy or game (for children or adults), that can be sold in stores for $15 or less (this means that it must cost less than $5 to make in volume). You must have a prototype and proof that it is indeed new: show what toys are similar in what the differences are.
  2. A simple device that will help the handicapped or the elderly, or anyone in a household. A patentable prototype must be presented, showing that indeed it is new. It is anticipated that substantial market research will be necessary.
- Project #2: the main project: a patentable technology (new, useful, not obvious) of your own. The only limit is the seed funding and the need to have a working prototype by semester's end.

You may team up with others, but then I will expect multiple projects from your team: as many as people in your team.

APPENDIX B: MORE STUDENTS' EXPERIENCES

- A team of two students: J. D. and J. G. (seniors, Manufacturing) scored a success with their little four-week toy. They invented a simple plastic 'swimming pool cannon,' capable of propelling a ball with terrific force when slammed against the surface of the water. An alumnus who attended their presentation was quite taken by it, and spent time trying to find an outlet. His efforts yielded fruit in a few months, so that the toy will hopefully be seen soon in the market.
- V. S.'s (junior, ME) most interesting idea is, curiously, his warm-up project: a board game called 'My Life Sucks' similar to Monopoly, but where the winner is the one to lose all his money first. The square names and card texts are all hilarious. Our testing has shown its potential as a party game. He should make a lot of money with this.
- M. R. and T. T. (seniors, ME and EE, respectively) teamed up to try to solve a problem that had been requested by a community organization. This club has a team for handicapped hockey players, who use hand-propelled sleds, rather than skates, to move on the ice. The project resulted in an improved design for a sled, sitting higher than conventional sleds and with built-in brakes. It is hoped that the new design will be utilized for training and for those who need to gain some confidence in sled hockey.
- T. C. and G. J. (both juniors in ME) felt terrible after their inventions were found in the market, almost exactly as in their prototypes, just a few months after they were done. This happens quite often with professional inventors, who think along parallel lines. Now they do not feel so bad, for they realize that this is a sign that they're inventive thinking is working. Next time they'll be the first. . .
- C. S. (junior, AE) invented a 'Modular Network Cabling System' which attracted an entrepreneur. They began discussions in earnest on how to launch the product as quickly as possible. 'It's kind of old now,' said Chris after spending a year in the effort. 'In a few years everything will be wireless.' He is now working on the wireless solution, which perhaps he will continue after graduation.
- Mike S.'s (junior, ME) project was a 'Drummer's Metronome' that is felt rather than heard. His prototype worked right the first time, something quite unusual. He is now awaiting graduation to launch the product.
- More recently, D. G. (senior, Manufacturing) developed a 'Tooltip Adaptor' that allows shops to use inexpensive carbide inserts as CNC tools. Even though the idea is quite simple, he is going to be able to get a good patent protection on it. We hope he can become a wealthy alumnus in a short order.

There are more, of course, but we mentioned these few here because they are particularly close to becoming commercial. In retrospective, it seems that the short time available in the class is an encouragement for students to quickly identify a need and develop a simple solution to meet it. Simple solutions are inexpensive to produce, easy to commercialize, and give better results in actual use. The proof is that nearly one fourth of the students involved have already shown signs that they understand it.

Francisco Ruiz is Associate Professor of Mechanical and Aerospace Engineering and Director of the Invention Center at the Illinois Institute of Technology, in Chicago. This

center was created as a studio where students could learn about invention as if they were working in a corporation. The class, which was funded by several grants from Government and private foundations, is now a requisite in the Kaplan Entrepreneurial Studies program, one of the few such programs based in an engineering school. When he is not inventing, Professor Ruiz is teaching Thermal Sciences courses or conducting research on combustion and engines, as he has been doing for the last sixteen years, except for short stints in industry and at the Kellogg School of Management (Northwestern University). He is also the author of seven SF novels and the current IIT Alma Mater.