The NCIIA Venture Capital Fund at Rowan University

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Abstract - The 8-semester Engineering Clinic sequence at Rowan University provides the venue for multidisciplinary student teams to engage in semester-long design and development projects. The majority of these projects are funded by local industry, faculty research grants or departmental budgets. Clearly, projects such as these are central to developing the design, problem solving and project management skills that are lacking in the traditional engineering coursework. Often missing, however, in the industry and faculty sponsored design projects, is the spirit of invention, innovation and entrepreneurship. One way to promote the entrepreneurial spirit is to provide students with the opportunity to propose their *own* original enterprises. Accordingly, funding from the National Collegiate Inventors and Innovators Alliance (NCIIA) has created a Venture Capital Fund, specifically ear-marked for the development of original inventions by multidisciplinary student teams within the Junior and Senior Engineering Clinics. Funding of up to $2500 per student team per semester is competitively awarded based on student-generated proposals to the Venture Capital Fund. To qualify for funding, student teams must propose, plan and implement an original, semester-long product development enterprise. The product idea must be successfully designed, developed and prototyped in a single semester. The latter criterion is possible given the unique rapid prototyping facilities available at Rowan University, which include a stereolithography machine, a multi-jet modeling rapid concept modeler, a rapid circuit prototyping system and multiple consumer appliance test stations. To date, ten projects have been funded through the Venture Capital Fund. These projects include a Portable MP3 Player, a 3COM Palm® RS232 Protocol Analyzer, an Automated Synchronized Spinning Exercise Cycle, a Coating Thickness Monitor, a Linear Combination Guitar Effects Processor, a Hybrid Rocket Motor Demonstrator, a Dorm-Sized Air Conditioner, a Hurricane Roof Vent and an Enhanced Four-Wheel Drive Suspension.

Introduction

In 1992, the local industrialist Henry M. Rowan made a $100 million donation to the then Glassboro State College in order to establish a high-quality engineering school in southern New Jersey. This gift has enabled the university to create one of the most innovative and forward-looking engineering programs in the country. The College of Engineering at Rowan University is composed of

four departments: Chemical Engineering (ChE); Civil and Environmental Engineering (CEE); Electrical and Computer Engineering (ECE); and Mechanical Engineering (ME). Each department has been designed to serve 25 to 30 students per year, resulting in 100 to 120 students per year in the College of Engineering. The size of the college has been optimized such that it is large enough to provide specialization in separate and credible departments, yet small enough to permit the creation of a truly multidisciplinary curriculum in which laboratory/design courses are offered simultaneously to all engineering students in all four disciplines. Indeed, the hallmark of the engineering program at Rowan University is the multidisciplinary, project-oriented Engineering Clinic sequence[1,2].

Table 1. Overview of course content in the 8-semester Engineering Clinic sequence.

Year	*Clinic Theme (Fall)*	*Clinic Theme (Spring)*
Frosh	Engineering Measurements	Competitive Assessment Lab
Soph	Total Quality Management	Multidisciplinary Design Project
Junior	Product/Process Development	Product/Process Development
Senior	Multidisciplinary Capstone Design Project	

The Engineering Clinic is a course that is taken each semester by every engineering student at Rowan University. In the Engineering Clinic, which is based on the medical school model, students and faculty from all four engineering departments work side-by-side on laboratory experiments, design projects, applied research and product development. Table 1 contains an overview of course content in the 8-semester engineering clinic sequence[3]. As shown in the table, while each clinic course has a specific theme, the underlying concept of engineering design pervades throughout.

The 4-year, 24-credit Engineering Clinic sequence offers students the opportunity to *incrementally* learn the science and art of design by continuously applying the technical skills they have obtained in traditional coursework. This just-in-time approach to engineering design education enables students to complete ambitious design projects as early as the sophomore year. And, by their junior and senior years, students are well equipped to embark on a completely original, entrepreneurial enterprise. This paper describes the ongoing results of an innovative venture capital system that allows students to competitively apply for funding opportunities to embark on such an enterprise. The Venture Capital Fund was created by a series of grants from the National Collegiate Inventors and Innovators Alliance (NCIIA), an initiative of the Lemelson Foundation.

The Venture Capital Fund for the Junior and Senior Engineering Clinics

The Junior and Senior Engineering Clinics feature a mixture of projects funded by industry and faculty research interests. Clearly, projects such as these are central to developing the design and problem solving skills that are lacking in the typical engineering curriculum. What is often missing, however, in the industry and faculty-created design projects, is the spirit of invention, innovation and entrepreneurship. One way to promote the entrepreneurial spirit is to provide students with the opportunity to propose their *own* original enterprises. Accordingly, we have created the Venture Capital Fund, specifically ear-marked for the development of original products by multidisciplinary student teams within the Junior and Senior Engineering Clinics[4].

Funding for student teams is competitively awarded based on student-generated proposals to the Venture Capital Fund. To be funded, a student proposal must describe an enterprise that meets the following criteria:

- The team must be multidisciplinary, including engineering students from at least two disciplines and, if possible, a student from outside engineering.
- The team must be organized into a company and must submit a business plan.
- The team must appoint a project director from the College of Engineering, an advisor from the College of Business, and an advisor from industry.
- The enterprise must consist of an original product idea that can be successfully designed, developed and prototyped in a single semester.

The latter criterion is possible given the unique set of rapid prototyping resources in place at Rowan University created in part by two separate NSF grants. The Competitive Assessment Laboratory (NSF DUE-9850563) features dedicated test stations for the complete engineering assessment of consumer products. Stereolithography: A Distributed Partnership (NSF DUE-9751651) has created a rapid prototyping center featuring a 3-D systems SLA-250 stereolithography machine, an Actua 2100 multi-jet modeling (MJM) rapid concept modeler, and a QuickCircuit rapid circuit prototyping machine. In addition to the externally funded projects described above, the College of Engineering is developing a state-of-the-art fabrication facility featuring advanced CNC (milling, turning, punch) and manual machine tools.

The Junior and Senior Engineering Clinics have a total enrollment of approximately 200 students distributed equally from each of the four engineering disciplines. However, all of the students do not embark on the entrepreneurial endeavor described above. The competitive proposal process, which rewards only those with original and thoroughly planned ideas, requires a significant effort at the start of the semester. In short, it is much easier for students to get "hired" into an industry or faculty sponsored project. However, with the availability of real funding, and the prospect of managing their own funds for a semester, interested and committed students with good ideas and entrepreneurial spirit choose to submit proposals.

In the Fall 1999 semester, proposals were accepted from 8 multidisciplinary student teams. In total, 11 ECE students, 13 ME students, 2 ChE students and 1 CEE student participated in these projects, which consisted of the following:

- Portable MP3 Player,
- 3COM Palm® RS232 Protocol Analyzer,
- Automated Synchronized Spinning Exercise Cycle,
- Coating Thickness Monitor,
- Linear Combination Guitar Effects Processor,
- Hybrid Rocket Motor Demonstrator,
- Dorm-Sized Air Conditioner, and
- Enhanced Four-Wheel Drive Suspension.

Several of these projects will be described briefly in the following sections.

One of the underlying themes in each of the student projects is that of rapid product development. In today's increasingly competitive environment, product development cycle times can no

longer be measured in years. This is particularly true in the consumer electronics industry where a delay of one or two months can result in a product that is obsolete before it is even introduced.

Portable MP3 Player

Within the past several years, advances in digital signal processing techniques, miniaturization/ decreased costs of RAM and increased consumer access to the Internet have caused a stir within the music industry. With the MP3 file format it is now possible to store approximately 10 hours of music on one Compact Disk and, since each individual song file is approximately 4 MB in size, these files can be readily downloaded from the Internet. While the latter activity is sometimes illegal, recording one's own CDs in MP3 format is not. Accordingly, there presently exists a rush to develop devices which capitalize on the MP3 technology.

Currently there are several portable MP3 players on the market which enable the user to store MP3 files directly into RAM, resulting in 30 to 60 minutes of music. As of this fall, there had yet to be a portable device on the market that allowed the user to play CDs in multiple formats, including standard music CDs and CDs containing files in MP3 format. With this potential market in mind, a junior ME student assembled a team that included himself and two ECE students (one junior and one senior). Their goal was to design and develop a portable MP3 player that met the following specifications:

Audio CD Compatible. The player must be able to read and play both standard music CDs and CDs containing files in MP3 format.

Automobile Docking Station. The player must have the capability of being used for personal moble use or within an automobile using a docking state.

Front End Loading. Since the unit has to be used in both personal and auto mode CDs must be front end loaded, similar to a typical automobile CD player.

Display. Using, for example, a 240x122 dot matrix LCD display, the user must be able to have access to a series of functions.

Figures 1 shows a version of a prototype breadboard circuit that the students built to learn how to communicate with the MP3 chip. The students acquired an MP3 decoder chip free of charge from the manufacturer and manufactured a printed circuit board using the QuickCircuit rapid circuit prototyping machine. Figure 2 is a Pro/ENGINEER assembly drawing of the MP3 player housing. The solid models were later imported to the 3D Systems stereolithography machine for rapid prototyping. A 240x122 dot matrix LCD display was also provided free of charge by a manufacturer. The Beta prototype is currently being built.

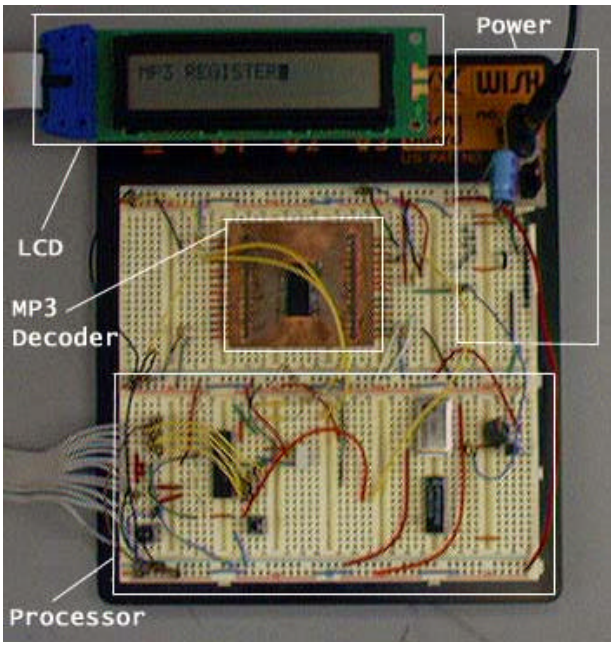

Figure 1. Prototype breadboard circuit for MP3 player. player.

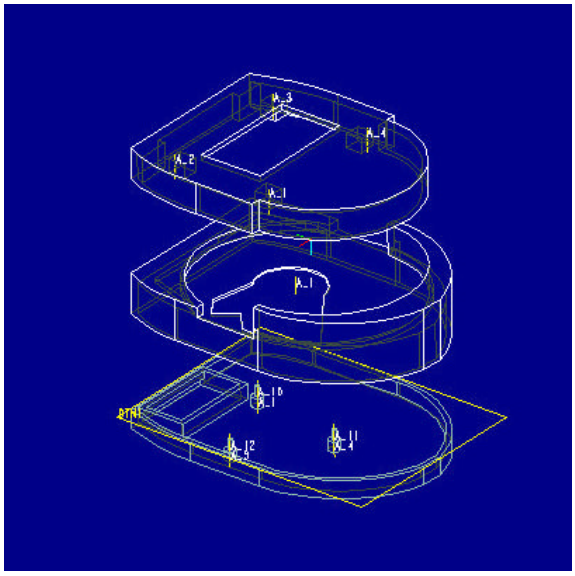

Figure 2. 3D model of housing for MP3

3COM Palm® RS232 Protocol Analyzer

Personal Digital Assistants (PDA's) such as the 3COM Palm computing environment and the variety of Windows CE devices represent another quickly growing market, whose potential may have only scarcely been tapped. For several hundred dollars it is now possible to own a fully programmable computer with 8 MB RAM and a graphical user interface that fits neatly in the palm of your hand. Apart from trying to reproduce typical desktop computing applications at a smaller scale, surprisingly few applications have been developed which take advantage of the mobile computing power available in the PDA environment. The field of instrumentation, for example, offers many potential applications that might take advantage of the PDA Computing platform

As an attempt to prove the capabilities of the PDA as an instrumentation platform, a team of two ECE students has been awarded a grant from the Venture Capital Fund to develop an RS232 protocol analyzer using the 3COM Palm computing platform. Currently available serial protocol analyzers are generally outdated, bulky, cumbersome, and difficult to use. The goal of the student team was to make a more compact, less expensive, and easier-to-use product by taking advantage of the standardized interface of the 3COM Palm.

The students decided on designing and developing an RS232 serial port protocol analyzer because many electronic devices communicate via the RS232 serial port. However, most analyzers in existence are very large, and therefore difficult for field technicians to use. The Palm Pilot has built-in serial port which made the development fairly straight forward.

To perform the project, the team purchased two 3COM Palm IIIx devices and a user license for the CodeWarrior Software which is used to program in the Palm computing platform. The

students have found that the Palm IIIx provides enough computing power to create a viable instrumentation platform. Furthermore, serial data acquisition and viewing can be achieved with only a minimal amount of external circuitry. Developing this instrument will lay a foundation for further development of other instruments which will utilize the RS-232 port of the Palm.

Coating Thickness Monitor

One of the hallmarks of the Engineering Clinic is interfacing with local industry. In many cases, these relationships result in ideas for original and innovative products. In this particular case, an original product idea was generated from work with a local manufacturer of coated aluminum products. As part of their manufacturing process, the company must apply coatings to rolled aluminum in accordance with specifications provided by their customers. Current methodology used by the company is a destructive sampling process in which a 6"x12" sample is cut from the finished spool and its mass is measured. Both sides of the sample are then stripped of the coating and the mass is determined again. The difference in mass is defined as the amount of coating per square foot. From this information, a coating thickness can be determined.

This method lends itself to errors in the accuracy of the mass balance as well as human errors in the cleaning of the specimen. These errors are especially important since the average amount of coating per square foot of aluminum is only a few milligrams. Also, the coating thickness is determined after the coating has been applied to the entire roll. Thus, if the desired amount of coating is not present, the process must be repeated to insure the application of the proper amount of lubricant.

For this project, a faculty member charged a student team to develop a method to nondestructively monitor the thickness of the coating as the aluminum is being rolled. In response, the team was rewarded with a grant from the Venture Capital Fund. The team consisted of two junior Mechanical Engineering students, one junior Civil and Environmental Engineering student and one senior Electrical and Computer Engineering student. In the proposed device, real time data of the coating thickness along the whole length of the spool will be provided, instead of just a measure of a small portion at the end of the spool. This will allow for adjustments to be made in the amount of lubricant applied to the aluminum it is being coated. Ultimately, this device will save the company precious manufacturing time and provide a more accurate assessment of the distribution of lubricant on the aluminum.

After examining four possible methods for monitoring the coating thickness, the students chose an optical method. This method determines the thickness of the coating by utilizing the reflections of a laser. In this method, a laser will project two reflections. Ideally, one beam will reflect off the top of the coating and the other off the top of the aluminum. The two reflections will then be detected by two photo diodes, denoted on the schematic below as detectors. These detectors will then determine the distance between the reflections.

Linear Combination Guitar Effects Pedal

In the Spring 1999 Sophomore Engineering Clinic, 35 students took part in a guitar effects pedal product development project.[5] The students were organized into 9 separate companies. In only 16 weeks, each company designed, developed, tested and manufactured a fully operational and market-ready prototype. As shown in Figure 3, the prototypes were manufactured using stereolithography and rapid circuit prototyping along with commercial-off-the-shelf components.

Figure 3. Guitar effects pedal prototypes.

While working on their sophomore audio development project, a group of three junior ECE students and one junior ME student uncovered a potential market for an innovative, yet simple and cost effective product. The product combines multiple effects in a way that allows the player to control the magnitude of each effect at all times. In current multi-effects processors, the magnitude of each effect is preprogrammed and each effect is simply turned on and off. The student design takes away the need for preprogramming these settings.

For the initial prototype, the students focused on combining two of the most popular guitar effects: distortion and chorus. The human interface is a single foot switch, which controls the multiple effects. If force is applied to the far right side of the switch, the device will produce 100% distortion. If force is applied half way to the right, then the effects processor will produce 75% distortion and 25% chorus. If force is applied to the center of the switch, the processor will produce 50% distortion and 50% chorus. The switch functionality is mirrored for the left or chorus side of the button. Figure 4 shows an Pro/ENGINEER assembly drawing of the prototype device which was manufactured using the stereolithography apparatus.

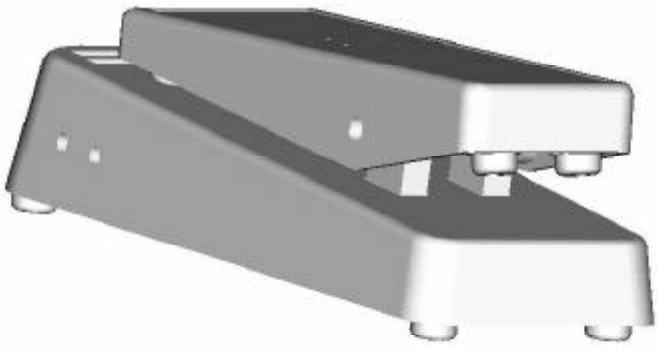

Figure 4. Linear combination Effects Pedal

The FanConditioner: A Dormitory Sized Air Conditioner

College dormitory rooms often become extremely hot during early fall and late spring months. This discomfort can make it difficult for the occupant to sleep well or carry out his/her daily activities. However, because of school power restrictions, residents are not permitted to use window mounted air conditioning units, which would typically require approximately 1000 Watts. Students are forced to use traditional fans as their only method of air circulation and cooling. Fans merely circulate the hot air around the room without decreasing the temperature of the air.

To satisfy this need, a team consisting of one senior ME student, one junior ChE student and one junior ECE student decided to design and develop a low-cost, low-power, dormitory-sized air-cooling device. The goal was to tap into the vast market of college students who are not permitted to use air conditioners in their dorm rooms and cannot afford other similar products in the market.

Research showed that the average dormitory has approximately two fans per student. The students probably spend approximately 30 dollars per fan, yet these devices do not solve the temperature problem. In a search of the prior art, the team members found several patented products that used evaporative cooling. However, these devices sold for $100 to $150 dollars.

After conducting experiments and or theoretical calculations on evaporative cooling technique, open loop water cooling, closed loop water cooling and vapor-compression refrigeration, the students decided to focus on a closed loop water cooled heat exchanger system. The system is currently under development and has been granted a no-cost extension for Spring 2000.

The Articulating Lift Block: An Enhanced 4-Wheel Drive Suspension Device

The majority of all mid-priced sport utility vehicles (SUV's), trucks, and even some vans sold in today's market have a suspension which consists of leaf springs with solid axles as opposed to air, independent, coil spring or torsion bar suspension systems. This is a result of the relative low cost and adequate support offered by a spring leaf suspension in comparison to higher priced independent suspensions that can be found on the higher priced SUV's and trucks on the market.

One of the major design characteristics of a suspension with leaf springs and solid axles is the unnecessary presence of torsional stresses that are produced in certain driving situations. The specific situation that causes these unnecessary torsional stresses in a leaf spring suspension occurs when the leaf spring is oriented in an off-camber-driving situation. This situation occurs frequently in any SUV or off-road pickup when driving on any type of off-road setting. The torsional stresses are a direct result of the suspension compression at one end of the axle and the suspension droop on the opposite end of the axle. With the leaf springs solidly clamped to the outer housing of the axle, the springs do not have the degrees of freedom required to avoid the torsional stresses placed on them. This is a recurring problem for any leaf spring suspension SUV or off-road pickup that is constantly subjected to off-road driving situations in which the driving surface is filled with rises and dips.

The constant application of unnecessary torsional stresses that are applied to the leaf spring degrade their mechanical integrity and ultimately affect the overall performance and longevity of the vehicle's suspension system. Elimination of the torsional stresses would not only improve the

performance of the leaf springs but also the longevity of use. Accordingly, a junior student from the Department of Mechanical Engineering proposed an original design to eliminate torsional stress in the leaf springs. To develop this product, the student assembled a team of 4 ME students.

The product will be incorporated into an after-market lift kit, which is a common device employed by SUV and off-road pickup owners to lift their suspension. Reasons for lifting the suspension include both greater ground clearance and increased room for larger tires. Both of these applications are useful to any one who is an off- road enthusiast and it also makes the vehicle look better. A standard lift kit comes with U bolts and lifting blocks.

Like a standard lift kit, the original student design is intended for aftermarket use as a complementary item that would work just like a lift kit but with the elimination of torsional stresses that are created with a standard lift kit. The articulating lift block is designed to reduce torsional strain on the leaf springs of a live axle suspension system, while at the same time improving the overall flexibility of the vehicle's entire suspension system. The device will also be durable enough to handle the rigors of off-road use.

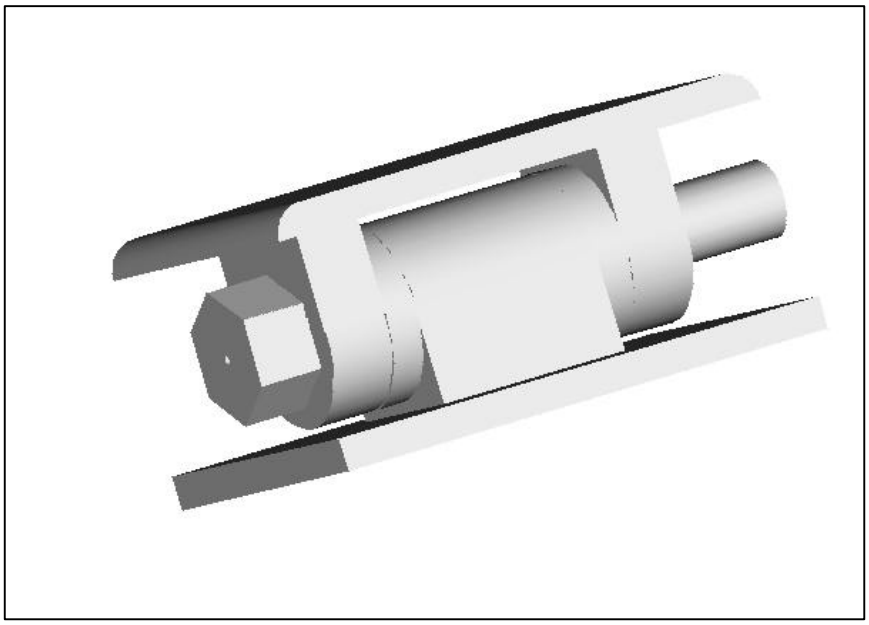

Figure 5. Articulating lift block for enhanced 4WD suspension.

As shown in Figure 5, the students designed and built a prototype of their lift block. The majority of the design components were purchased form various vendors. The only part of the design that required machining was the upper and lower parts of the housing block. The parts were machined manually using a vertical milling machine.

Having designed and built the prototype, current plans call for a rigorous testing schedule in Spring 2000 in which the students must test both the bi-directional strain of the leaf springs and the flexibility of the entire suspension. This will be performed with the test vehicle, a 1997 Jeep Cherokee Sport, in three stages of suspension development. Stage 1 will be in stock form, stage 2 will be with a standard 3" lift installed (front coil spacers & rear blocks) and Stage 3 will be with

the articulating lift blocks replacing the standard blocks in the rear. Bi-directional strain gages will be mounted to the top and bottom surfaces of the upper- and lowermost leaves, respectively, in each spring pack, both fore and aft of the axle. Eight bi-directional strain gages, for a total of 16 channels, will be used to take strain data from the leaf springs in the rear suspension of the Cherokee during both modes of vehicle testing, static and dynamic. Static tests will be done using a fork-lift and dynamic testing will be done on a local test track.

Conclusions

The activities described herein were funded by two separate grants from the NCIIA. In the first year of the project (Fall '98/Spring '99), only two teams applied to our Venture Capital Fund and only one team was funded. In Fall '99, 8 teams were awarded projects funded by the Venture Capital Fund. Our experience has shown that, while many students have ideas for original inventions, the majority of the students do not have the desire to formalize these ideas into a solid proposal. This was a surprise at first, given what we believed to be significant incentives of funding and team autonomy. In the Fall '99 semester we were delighted at the amount of number who expressed desire to work on an original product development project. A major reason for the change in student attitudes is that, having observed the initial team in action, many others were motivated to propose their own ideas. In short, the word has spread among the students. After 3 semesters of the supporting original student projects from the Venture Capital Fund, a steady-state participation level of 4 projects per semester is anticipated.

The original plan for the entrepreneurial projects required that all work be completed in one semester. In some cases, this has been possible but in many cases no-cost extensions have been granted to the student teams to continue work for a second semester. However, each individual department at Rowan has the power to remove a student from a project if the project is failing to meet the proper educational requirements. To date, this has not occurred.

Ultimately, the Venture Capital Fund cannot be successful without a cadre of faculty willing to buy in to the concept. Faculty members are needed to help encourage invention within their traditional coursework and be willing to supervise students if they propose original inventions. Initially, there may have been a hesitancy to participate in this endeavor for several reasons. Firstly, there appears to be an inherent misconception that all inventions are electromechanical widgets. This misconception arises from the vision of the inventor as Thomas Edison tinkering in his laboratory. The reality is that the U.S. Patent Office issues utility patents for biotechnology, computer software, chemical processes as well as electronic and mechanical devices [6]. Secondly, even if faculty members understand the wide variety of potential inventions, they often see themselves as researchers, not inventors. Fortunately, the word has spread among faculty members as well. In the Fall '99 semester, 8 out of 28 faculty members within the College of Engineering supervised entrepreneurial development projects funded by the Venture Capital Fund.

Acknowledgments

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