Creating a Truly Multidisciplinary Entrepreneurial Educational Environment

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Abstract

In our age of technological growth and change, the role of the engineer has evolved from lone specialist to team player, from internally focused to globally aware, from reactionary to entrepreneur. The entrepreneur has created much of our social wealth. The characteristics of the entrepreneur transcend academic disciplines, and social as well as economic status. To foster these characteristics among its students, Lehigh University is developing a multidisciplinary educational environment where entrepreneurial spirit can flourish. Lehigh's academic programs in Integrated Product, Process and Project (iP^3), Integrated Business and Engineering (IBE), and Integrated Design Arts (IDA) integrate across Engineering, Business and Design Arts through sponsored projects and entrepreneurial teams or e-teams consisting of students, faculty advisors, staff support and company mentors. Project sponsors include the full range from student entrepreneurs and other start-up companies, to established small, medium and large corporations. The multi-level approach to curricular integration includes pre-college outreach, freshman projects, curricula support, capstone projects and graduate projects. The educational environment includes a Campus Center for Entrepreneurial projects; an entire building designed to support students project teams. This paper will discuss the design and implementation of these programs, our assessment and evaluation methods, lessons learned and future plans for improving this environment.

1. Introduction

The engineer as inventor is certainly not new. Many innovative products that we enjoy today were invented and created by engineers, but what about the engineer as entrepreneur? Textbook authors write and students study engineering design, concurrent engineering and design in a broad context.[1,2,3,4] The question that confronts those that teach design is how broad and inclusive is the context that is presented to the our student. Many schools have addressed this issues in the capstone project class[5] [This reference contains an additional 36 references of various schools' approaches]. Our answer is "as broad as possible" including engineering,

business, industrial design and social sciences. To achieve this broadest possible context, Lehigh students work in multidisciplinary teams with company sponsors on real world projects requiring deliverable prototypes and business plans. Based on the industry feedback of the past four years this active, collaborative, project-based learning is superior for developing the characteristics valued by employers. These characteristics include professional competency, industry experience, multi-functional communications skills, team-orientation, problem solving and decision making skills in ill-structured situations and self direction. We believe that this experiential learning approach is equally valid for the student entrepreneurs. The approach is to partner the entrepreneurial teams (e-teams) with start-up companies, student entrepreneurs and others that have the entrepreneurial characteristics and potential for success. To modify the familiar saying, "familiarity breeds not contempt, but imitation."

Lehigh University has three notable programs that have embraced the e-team project approach. The first and most established program is the Integrated Product, Process and Project (iP^3) Program. The second is a new program in Integrated Design Arts (IDA). The third is also new, the Integrated Business and Engineering (IBE) Program. Both the IDA and IBE programs offer degrees, while iP^3 is designed to support existing majors.

2. Integrated Product, Process and Project (iP^3) Program

Lehigh's Integrated Product, Process and Project Program provides a support structure to promote curricular and course adaptation of the e-team project approach to education across the Lehigh campus. The ***Integrated*** part of IP^3 refers to the requirement that the project team includes as many participants with varied background and capabilities as is needed to create successful projects teams. It also means that the courses are integrated into various undergraduate and graduate curricula. Mechanical Engineering and Mechanics has taken the lead in adopting this approach. The $\boldsymbol{P^3}$ in the iP^3 Program context is any electro-mechanical-optical device, software, chemical process, manufacturing process, a project or study that is to be delivered to an external sponsor. The program also emphasizes the development process itself, where the e-team is expected to follow methods and best practices to manage the project, document decisions and communicate results. The iP^3 Program encourages student entrepreneurs from all disciplines to innovate and create within the realities of engineering, industrial design and business feasibility. As shown in Figure 1, the iP^3 Program focuses on 5 major areas: Pre College Outreach, Freshman Design Projects, Engineering/Business/Design Arts Sequences, Capstone Projects and Graduate Programs.

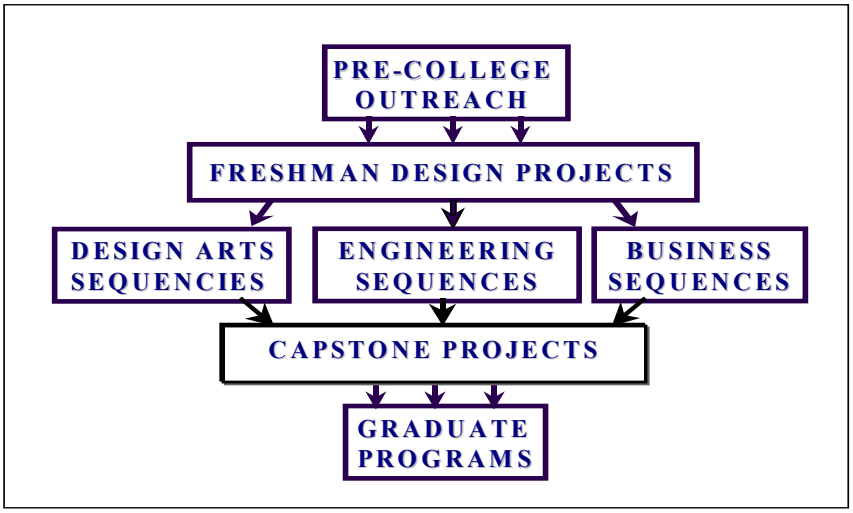

Figure 1. iP^3 Program Structure

Pre College Outreach

The **Career Awareness Program (CAP)** at Lehigh University involves the Colleges of Engineering and Applied Science, Business and Economics, and Arts and Sciences. With financial and personnel assistance from companies such as Ernst & Young and Alcoa, CAP supports the achievement of greater diversity by attracting, engaging, and mentoring the brightest pre-college students of color. This recruitment/leadership development initiative introduces the participants to the e-team project experience in accounting (ACAP), industrial design (IDCAP) and engineering (ECAP).

High school students from populations traditionally under-represented in many business and science disciplines gain an insightful view of the needs of corporate America in the first summer of this program. They also begin to learn the value of each individual's unique combination of skills, culture, and customs. CAP pursues the dual goals of giving talented young people an intensive, comprehensive overview of the various careers in Engineering, Business, and Arts & Sciences, and introducing them to multi-disciplinary, team-based projects.

CAP will have the following four phases: i) a one-week summer residential academic program beginning with approximately 25 to 30 students in each area, including active team-based projects with concrete deliverables integrated throughout the program; ii) fall semester follow-up programs and assessment; iii) for those students who matriculate at Lehigh, a pre-freshman year summer of credit-bearing regular courses; and iv) mentoring and retention initiatives to ensure the academic competitiveness of these students and to facilitate their early selection of internship and summer job opportunities.

The CAP summer courses are a jointly supported by the University's Iacocca Institute. More information on the programs can be found at www.iacocca-lehigh.org/cap/.

Freshman Design Projects

The ***Freshman Projects Course*** is the first course for the Integrated Business and Engineering (IBE) majors (See section 4 below). It is designed to start the new matriculating student on the journey of team-based experiential learning and get students from all majors interested in integrated product, process and project development. The teams of students work on reverse engineering (design and business too) existing products. Teams consist of freshman from all three undergraduate colleges who participate in team building exercises and communications skill development while taking existing products apart to discover: Why it has certain forms and features? How the product works? How and where it was manufactured, assembled, and tested? What are the competing products? Where can it be purchased? What are the costs of components? What is the final price? What is the volume sold? Why were specific colors and shapes of the product selected? Who are the target customers? What are the target specifications? How were they determined? What are the appropriate patents?

Finally, the team must recommend how to improve some aspect of the product, process or project. Students are exposed to enabling technologies such as model making and geometric modeling, financial modeling and competitive analysis as well as best practices and methods including product data management, documentation and other standards. Field trips to the sponsoring company or suppliers are common. The students must document their work and communicate the results through sketches (as shown in Figure 2), models, written report, posters

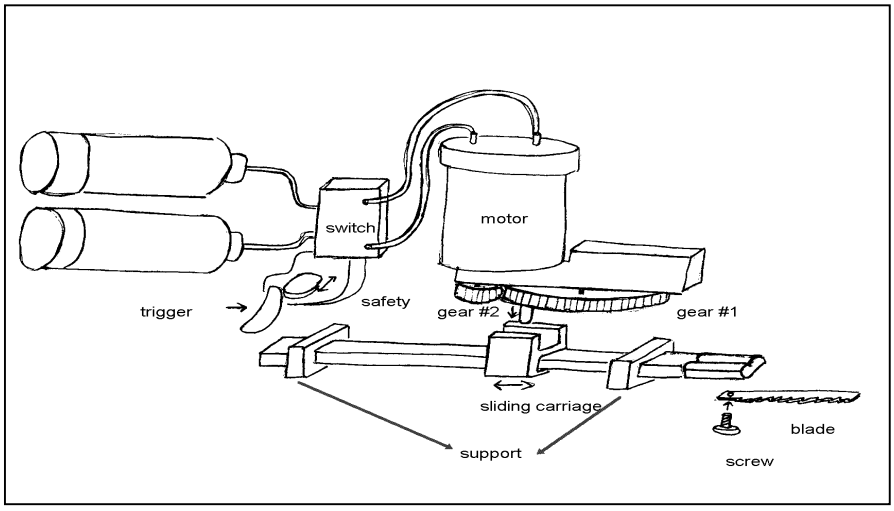

Figure 2. Student Sketch of Black & Decker Reciprocating Saw Drive Mechanism

and oral presentations. The course stresses teamwork, team management, team leadership, individual responsibility, as well as introductions to enabling technologies such as CAD/CAM, rapid prototyping, modeling and simulations tools.

Design Arts/Engineering/Business Sequences

The various ***Sequences*** are the responsibility of individual departments and colleges to develop the discipline specific skill sets, cultural awareness and general education needed to succeed in life. Where possible, the iP^3 Program provides seed funding and support for relevant initiatives.

Based on the skills needed to complete the capstone projects, the engineering sequences focus on solids modeling, CAD/CAM, rapid prototyping, assembly modeling, geometric dimensioning and tolerancing, design for manufacturing (DFX), functional modeling and simulation, manufacturing process modeling and simulation, quality methods, mechatronics, kinematics, thermodynamics, mechanics, materials, software and data base issues. The business functional and integrative skills include business planning, customer and competitive analysis, segmenting and targeting markets, product positioning, value chain, supplier management, operations management, information systems, coat and managerial accounting, capital budgeting financial management investment and risk analysis, statistical methods, competitive strategies, organizational design, business and economic policy.

From a programmatic point of view, the current focus of the iP^3 Program's support in the College of Business and Economics is e-commerce with the new Business Information Systems (BIS) major and Supply Chain Management major. In the College of Arts and Sciences the effort is in Integrated Design Arts within the Department of Arts and Architecture (see section 3 below). In the Rossin College of Engineering and Applied Sciences the focus has been on expanding the successful implementation of the Department of Mechanical Engineering and Mechanics to the other engineering majors.

Capstone Projects

In the ***Capstone Projects*** course students form multidisciplinary e-teams to develop new products, new software or new processes. They are capstone in the sense that they require the application of the accumulated knowledge and skills to actual problems with actual clients. In 1999, iP^3's sixth year of projects, there were 26 teams with over 130 students from engineering, business, arts and science from over 20 majors. In the two-semester project course the e-team must determine customer needs, product specifications and constraints, target markets and channels, develop and select alternate design concepts, build models, simulate performance, develop costs and financial feasibility. The teams are encouraged to work closely with company sponsors to determine manufacturing, distribution or other strategic capabilities, supplier network, marketing and distribution methods, corporate positioning of product lines, competitive benchmark competition, financial justification and limitations, market introduction timelines, and volume and pricing strategies. Each team must present the results of their technical and

economic feasibility analysis to the faculty advisors and sponsor through posters, written reports and public oral presentations.

In the second semester the e-teams create a working prototype and develop a business plan to bring the product to market, a product/company portfolio and product packaging. The working prototype may consist of the entire product or a relevant subsystem. Documentation includes 3-D solids assembly model, piece part models and dimensioned drawings, bill of materials, assembly and tooling models and drawings. As appropriate, plans for production, assembly and quality assurance are developed. The business plan is the governing document for the team's efforts. The plan includes the financial justification, business case, competitive strategy, assessment of risk and business forecasts. Each team is expected to create a base case financial model and cash flow projections for their project, including sensitivity analysis under various assumptions

A project notebook and portfolio document the product development process in words and images and act as a marketing vehicle for the product, the company and the iP^3 Program. Again, the results must be presented in report and poster form and oral presentations to the sponsors.

Project sponsors and project funding fall into five categories: 1) industry sponsors, 2) state sponsored entrepreneurs, 3) federally sponsored entrepreneurs, 4) Lemelson Foundation-sponsored student entrepreneurs, 4) IP^3 Program-sponsored student and faculty entrepreneurs and 5) self-funded entrepreneurs. For the year 2000, there were 7 industry sponsored projects. These included Lockheed Martin, Black & Decker, The Knoll Group, IBM, Ingersoll-Rand, TNO Institute of Technology (Netherlands). The State of Pennsylvania's Ben Franklin Technology Center funded three projects. These early stage companies included PVI Unlimited, Patient Handling Technologies and Pulmonary Services Inc. The Lemelson foundation through the National Collegiate Inventors and Innovators Alliance (NCIIA) founded three student projects; a digital resume service; a radar gun – weather station system for pitching monitoring and analysis; and a mountain bike suspension system. The bike suspension project was featured at the summer 2000 Smithsonian Institute's national bicycle innovation showcase "Re-inventing the Wheel". The Bike project and the radar gun were featured in the American Society of Mechanical Engineers (ASME) magazine[6,7]. Finally, The iP^3 Program funded two projects, the ASME 2000 design competition and Landmark Signs. The latter is a marketing technology that was a winner of our annual "Invitation to Innovation." Student projects are solicited each fall through this campus wide competition. Winners receive a project expense budget and help creating an e-team.

In the process of identifying potential clients, local entrepreneurs are directed to the capstone project course through the Small Business Development Center. Previous year's successes with local entrepreneurs include Richard Roland's Neo Products J-2 spitfire violin (www.voicenet.com/~neopro/) as shown in Figure 3, Matthew Hoey's Corian Chair

(www.matthewhoey.com/) as shown in Figure 4. Both are currently on the market and rely significantly on design and business recommendations by the multidisciplinary student e-teams. The chair has subsequently been featured several times in the New York Times and appears in national television commercials for DuPont Corian ™. Another "most likely to succeed project" is shown in Figure 5. This figure shows a student member of the e-team demonstrating Jack Plesnik's Karate Scoring Apparatus at the NCIIA's March Madness of the Mind exhibition at the Smithsonian Institute in Washington DC, in March, 2000. Mr Plesnik's business plan is currently circulating among potential backers.

Figure 3. Example of Neo Products' Violin from 1997 Capstone Projects Course

Figure 4. Matthew Hoey's Corian Chair from 1998 Capstone Project Course

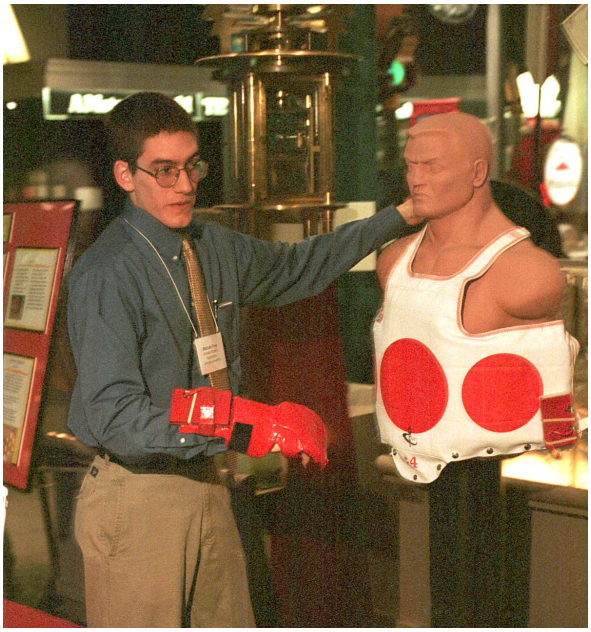

Figure 5. E-team member, Mike Frey demonstrates the Karate Scoring Apparatus

In the spring of 2001 with funding from the Federal Department of Labor the iP^3 Program will initiate an outreach program to attract entrepreneurs from the local area to work with the e-teams to develop business plans and working prototypes[8,9,10]. With funding from the Federal Department of Education[11] and a grant from NASA and the Community of Agile Partners in Education (CAPE)[12], the program is investigating ways to globalize the e-teams based on the experiences gained from the graduate IPD courses.

Graduate Programs

The ***Graduate Program*** in Integrated Product Development (IPD) leads to a Masters of Engineering. The program is 30 credits with 18 in Mechanical Engineering major field and 12 in a minor field such as business, design arts or other engineering disciplines such as industrial engineering, material engineering or computer engineering. Of the 18 credits 6 are in for a project completed at a sponsoring company. In part of the program for the past two years, the Lehigh students enrolled in the graduate course ME450 IPD have worked in international e-teams with students from Fontys University in the Netherlands and The Otto-von-Guericke University of Magdeburg, Germany. Using video conferencing, the Internet and phone the teams with at least three members from each school, have developed products for Philips Electronics[13,14]. Figure 6 shows a German member of one of the teams sharing details of their design with the other team members at Lehigh and in the Netherlands. Lessons learned from this experience are being implemented at the undergraduate level for a regionally dispersed e-team in the project year 2001 with funding from NASA/CAPE and the Department of Education.

Figure 6. Design evaluation of a Philips product via international video conferencing

3. Integrated Design Arts

The Integrated Design Arts Program is an offshoot of the iP^3 Program and a natural evolution of the Department of Art and Architecture to become the campus center for design arts education. In spring 2000 the department received faculty approval for an ID minor consisting of the following courses: sketching and rendering, color theory, 2D & 3D visualization techniques, ergonomics, design aesthetics and ethics, 29th Century ID and the capstone e-team projects course. Figure 7 shows an example of a series of studies that lead the student to understand the psychology of color used in advertising, marketing, architecture, product design and fine arts. Figure 8 shows an example of an introductory student project, designing a faucet using proportion theory, sketching and rendering.

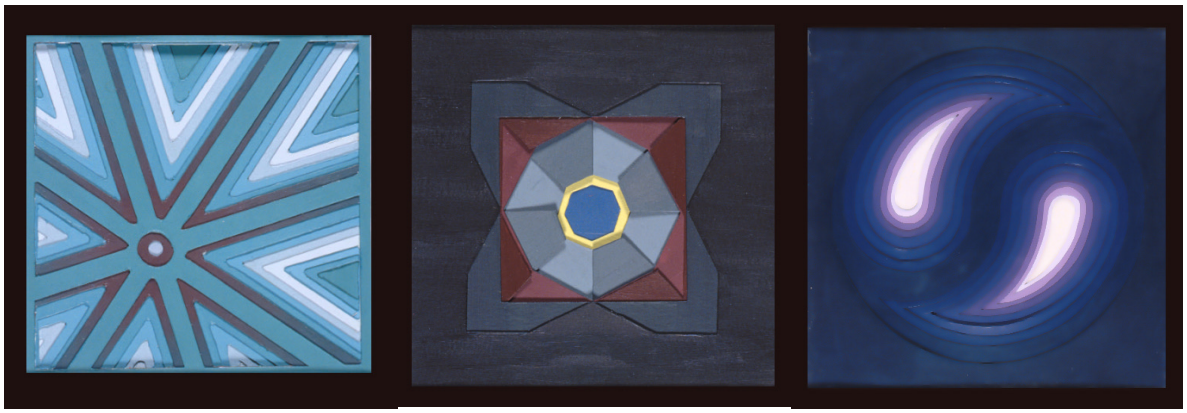

Figure 7. Color theory examples from Integrated Design Arts Course

Figure 8. Student project in proportional systems, 3D modeling and rendering

In the evolution of the e-teams, the inclusion of ID students has had a profound effect on the quality and the aesthetics of the designs, as Figures 3 and 4 of the violin and chair can attest. As funding for new positions become available, the IDA program is expected to grow both in the number of minors from engineering and business and the number of majors.

4. Integrated Business and Engineering (IBE) Program (www.lehigh.edu/~inibe/)
In the fall of 2000 Lehigh admitted it first class majors. This honors program offers students a joint BS in Business and Engineering, with the opportunity to major in an engineering or business concentration area while taking a variety of courses in business, engineering and arts. This program has language proficiency requirement as well as summer internship and study abroad opportunities. The program features the freshman projects course and the capstone e-team experience as described above and special seminars each semester. This first year class has 35 students selected from over 600 applicants with a combined average SAT of over 1400. It is expected that this program will grow in both quality and quantity of students. At the steady state the program is expected have over 250 students enrolled. A faculty implementation team is currently exploring the possibility of a graduate program that integrates a Masters of Business Administration (MBA) and Masters of Engineering (MEngr.) again using the e-team project as an integrating theme.

5. Infrastructure Requirements – faculty, staff, facilities
The three programs (iP^3, IDA and IBE) described above emphasize the integrated, multidisciplinary nature of engineering education, using e-team projects as a means to this end. The multi level approach from pre-college to graduate programs requires a commitment to an infra structure to support the faculty and students involved in the various courses.

Faculty
All of the programs described are faculty intensive. As such, the advising that is a keystone to the e-team success must be shared. For the year 2000 capstone course, four faculty were

responsible for team teaching the lectures and 17 faculty from 4 departments advised the e-teams. With these numbers, coordination and consistency are critical. The programs are experiences rapid growth in the number of students, the number of e-teams and the number and type of projects. Various departments have determined that all faculty members are responsible for advising undergraduate design projects. Mechanical Engineering has taken the lead in this effort, Material Science and Engineering, Electrical Engineering and Computer Science has followed. To attract and maintain faculty interest, it is imperative that a support structure be in place to identify e-team projects, provide an opportunity for faculty innovation and invention and to help manage the financial resources and logistics needed to complete project on time and on budget. This is being accomplished with excellent support staff.

Project and Program Staff Support

To date the iP^3 Program has developed funding for staff to support the e-teams. The staff includes a program director, an outreach manager, a program manager and an academic associate to coordinate students, faculty, sponsors and facilities. Various laboratories funded and operated by departments, institutes and centers house the technologies needed by the teams to create successful prototypes. E-teams are funded to pay for the use of these facilities. E-teams are funded to purchase the various devices, subsystems and components needed to complete their projects. Staff support the faculty advisors in managing and controlling accounts payable, accounts receivable, shipping and receiving, project documentation, written, oral and poster reports for over 25 e-teams with over 130 students and five different labs. The outreach manager is the interface between the sponsoring companies, state and federal agencies, entrepreneurs and the faculty.

Through the fiscal year 2003, the iP^3 staff support is funded by grants from the Department of Education and the Department of Labor. This soft money support will have to be replaced thereafter with budget support from a combination of new endowment and reallocation of existing positions. This financial support is based on the perceived value of the programs relative to other initiatives and the university's strategic direction.

Facilities

A strategic mission of the university is to offer a differentiating educational experience for its undergraduates. To that end the current administration has provided the iP^3 Program an entire existing historic building to support e-team projects from pre-college outreach to graduate programs. The 17,000 sq. ft. facility is scheduled for renovations beginning the summer of 2001 and occupancy by the fall semester 2002. The building will support summer program in career awareness, entrepreneurism, methods of innovation and invention, freshman e-team projects, capstone e-team projects and graduate projects. It will encompass computer applications, shop and fabrication labs and industrial design studios. It will be the campus center for e-team projects. Figure 9 shows a computer rendering from a student generated Alias/Wavefront computer animation of the renovated building.

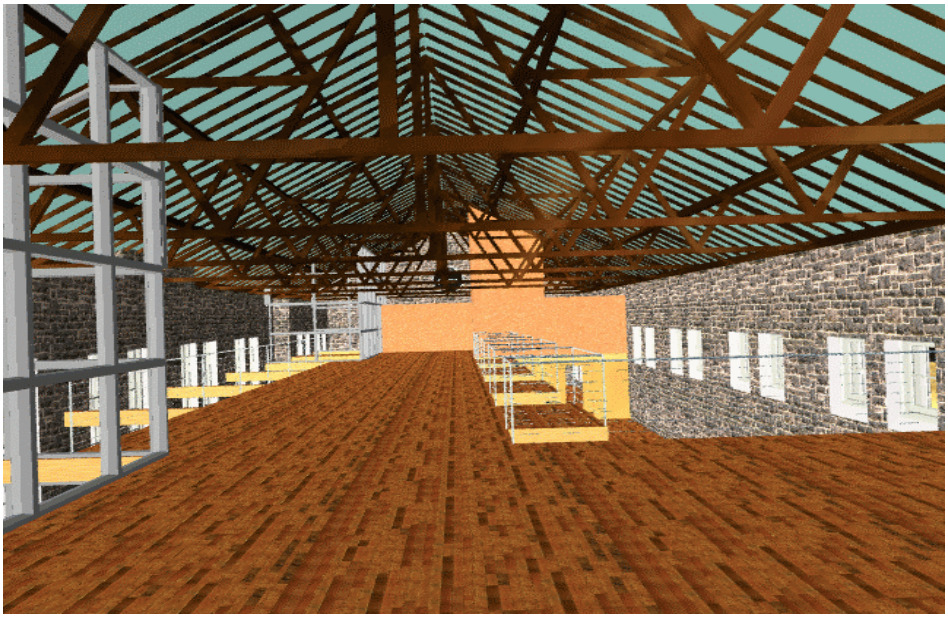

Figure 9. Computer rendering of the third floor of the campus center for e-team project

Program Evaluation

In keeping with the methods and procedures of the Department of Labor and in preparation for ABET accreditation, three evaluation activities will be conducted to demonstrate that programs objectives are being met with particular focus on entrepreneurs[10,15]. The first involves a *descriptive evaluation*, in which the planning process, project implementation, and outcomes are documented and reported on an annual basis. The second activity, the *operational evaluation* involves a feedback loop, in which information about the strengths or weaknesses of the program are funneled back to project administrators, so they can address potential problems and provide continued support for useful practices. The *outcome evaluation* is intended to address the final part of the objective, that is, to assess the impact of the programs on the university. The methods that will be used to carry out each of these evaluation activities are described in detail in Reference 10.

To help with the evaluation iP^3 Program has hired a part-time research engineer from Lehigh's Center for Social Science Research as well as an outside evaluation consultant. Evaluation and yearly progress reports will be reviewed by the iP^3 Program's 5-person faculty steering committee and its 13-person industry advisory board before they are submitted to the university administration.

6. Lessons Learned

Since 1995 over 900 students have participated in over 150 project teams with over 100 industry

sponsors. Over these years the vast majority of project teams have worked for existing industries. As the numbers of projects increase and the numbers of entrepreneurial projects increase, there will be opportunities to learn from our mistakes and improve the experience for the students, faculty, staff and sponsors.

From an e-team point of view, many student participants express that while the course is challenging and at times frustrating for them, it is a great and unique experience. In particular the experience gives them a competitive edge in job hunting. Most participating students report that the job interviews focus on their project team experiences and the students are able to show perspective employers concrete evidence of what they have accomplished.

Our teams are not, however, without rough edges. The most often reported problem the teams have is in the area of teaming skills. In our case the team includes students, faculty advisors, staff and sponsors. Some examples of issues include: wanting to "fire" a team member for poor performance; wanting to "fire" a faculty advisor; and lack of cooperation from a sponsor. Sponsor expectations have also been a problem. On one extreme a large corporation may simply give money but not allocate mentoring time. On the other extreme, entrepreneurs who are working with a team may want to be on campus constantly and see to expect the students to ignore all other work except their project. Surprisingly there has been little difficulty with sponsors whose projects have been found to be technically or economically infeasible. To address these issues, a crisis team approach is being developed to identify and remediate dysfunctional teams. Led by outside consultants, the team will help negotiate solutions as well as educate team members on communications and consensus building methods.

From a management point of view the key to success for developing programs like iP^3, IDA and IBE is to think big, get top-level approval, then implement from the bottom up with small pilot projects and learn how to make the experience scaleable and sustainable. To have the longest-lasting impact, the approach needs to be incorporated into a curriculum. This takes time, energy and demonstrated success to convince successive departments about the benefits of changing. However, we firmly believe it is well worth the effort.

A major organizational issue is organizing cross-functional teams within a functionally structured university. This is typical referred to as a matrix structure, with the functional organizations in our case being departments and colleges. To acquire real clout within the classical university structure requires financial resources, which are in high demand by and short supply for existing departments and colleges. Without consistent support at the provost level, the ability to organize courses and faculty teaching loads, that integrate across departments and colleges, will be thwarted by internal resistance to share scare resources.

7. Future Activities

The iP^3 Program is growing by 20% each year. With funding from the Department of Labor, the

iP^3 Program will actively seek out entrepreneurs and by working with student e-teams, assist them in developing business plans and working prototypes. The IBE Program is expected to double next year and the IDA Program is expected to have even greater growth. The need for planning for this growth is obvious. Shared faculty participation and adequate infrastructure of support staff and facilities are key to successful implementation.

With funding from the Department of Education the iP^3 Program will be investigating and implementing international components to at least some e-team projects. This work will be coordinated with Lehigh University Iacocca Institute's Global Village. The Global Village is a six-week program that brings 75 foreign entrepreneurs to Lehigh's campus each summer. (www.lehigh.edu/~village/). In the summer of 2001, an e-team will attend and discuss possible international projects.

The need for sustained funding of the infrastructure to support these and other campus initiatives is also obvious. Continued fundraising for the renovated Campus Center for Entrepreneurial Projects and eventual move of staff lines to hard budgets remains a major priority. It is the responsibility of the program management to document the value of these programs as a strategically differentiating characteristic of a Lehigh education and worthy of continuous funding. This evaluation, documentation and internal sales will continue for the next three years and the end of the federal funding.

8. Summary

Lehigh University has invested in several new initiatives to transform engineering, business and design arts education by integrating engineering, business and industrial design through curricula and e-team projects. The multi level approach starts with pre college outreach and continues through graduate programs. The Integrated Product, Process and Project Program focuses on entrepreneurial teams of students working with industry mentors, faculty advisors and program staff to create new products and the means to bring them to market. Student and industry sponsor response to these programs has been favorable and the programs continue to draw more students and industrial support.

We believe that Lehigh's multidisciplinary undergraduate programs are unique in design, scope and breadth of implementation. Keys to the success of the programs are the shared responsibility of the faculty across several participating departments, the incorporation of the projects and courses into various curricula and the staff and facilities infrastructure to support the programs and e-team projects. While currently relying on external funding from grants and alumni support, the long-term challenge is to incorporate the program's funding into the university's budget.

Acknowledgments

The programs described in this paper have been developed with the assistance and support of a number of talented people. The faculty advisors take the brunt of the work interacting with the e-

teams. We thank Kathy Katcher, the iP^3 Program Manager, for her work ethic, integrity, loyalty and patience as together we create this program. We are thankful for the support of the university administration, President Greg Farrington, Provost Ron Yoshida, Dean Bobb Carson, Dean John Chen and Dean Richard Durand for their continued encouragement, financial support and release time to work on these programs. In particular, we acknowledge the work of Bill Michalerya, Associate Vice-Provost for Research, who believed in the objectives and goals of the iP^3 Program and helped us secure federal funding from the Department of Education and the Department of Labor. In addition we appreciate the participation and financial support from the Northeast Tier Ben Franklin Technology Center, the Small Business Development Center and the Lehigh Valley Workforce Investment Board. Additional financial support for the projects comes from grants from companies. This effort has been lead by Carol Carpenter, the Director of Lehigh's corporate relations. Also, we acknowledge the continuing work of the staff of Lehigh's Development office who have helped raised the several million dollars needed to renovate the new campus center. Finally, a special thanks to the staff of the NCIIA and the Lemelson Foundation for their continued support of student e-teams.

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JOHN B. OCHS

Professor John B Ochs has been teaching engineering design at Lehigh University since 1979. Since 1995 he has work with an interdisciplinary team of faculty and students from business and arts to establish undergraduate and graduate curricula focusing on experiential learning through industry projects. The award winning IPD program is now in its 6th year with over 150 industry-sponsored projects and over 750 student participants. In addition to the IPD program Professor Ochs is the founder and director of the Mechanical Engineering and Mechanics Computer Aided Design Lab and co-director of the Dravo Design and Prototype Shop. Professor Ochs teaches and does research in Computer Graphics for Engineering Design, Geometric Dimensions and Tolerances, Manufacturing, and many types of computer graphics modeling and simulations. Professor Ochs has been involved in several startups, two of which have been moderately successful. He is a member of the Acoustical Society of America, the Society of Manufacturing Engineers, the American Society of Mechanical Engineers and Phi Kappa Phi.

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Todd A. Watkins is the Faculty Fellow to the Provost and Associate Professor in the College of Business & Economics at Lehigh University. Professor Watkins holds Ph.D. and M.P.P. degrees from Harvard University, and a B.S. from the University of Rochester. He previously worked in optical design and optic manufacturing engineering at Eastman Kodak. His research involves the economics of innovation, defense industry & dual-use manufacturing, and technology policy. Teaching areas encompass the role of technology in trade & economic growth; as well as managerial economics; and new product development. As faculty fellow, he directs Lehigh's Venture initiative, which promotes innovation, inquery-based, experimental curriculum throughout the university. He founded and serves as co-director of Lehigh's Community Research and Policy Service (Lehigh COPRS), and was one of the founders of Lehigh's iP^3 Program, national winner of the ASME Curriculum Innovation Award. Watkins also won the 1999 Outstanding Instructor award from the National Technology University, for his teaching via distance learning.

BERRISFORD W. BOOTHE

Berrisford Boothe is an associate professor of Art and Design in the department of Art and Architecture and has been at Lehigh since 1989. A graduate of Lafayette College and The Maryland Institute College of Art, Boothe has been the recipient a Walters Museum Travelling Fellowship and two Jr. Faculty fellowships at Lehigh for his work in developing of an interactive web-based multimedia program with a physicist and multi-media composer. He's served on the Pennsylvania Council on the Arts and has been published in various art journals/ books including *Art News, Art Visions Magazine*, The Fine Artist Guide to Marketing and Self-Promotion and the just published Collecting African-American Art: Works on Paper and Canvas. In recent years, Boothe has been fundraising, coordinating and implementing an Industrial Design minor at Lehigh. Boothe also teaches Advanced Drawing, 2-D & 3-D Design, Painting, Contemporary American and African-American Art History and has team-taught courses in Graphic and Exhibit Design. Currently, Professor Boothe is one of a small group of faculty from across all three undergraduate colleges implementing the IPD Integrated Product Development initiative - partnering students from Engineering, Business & the Design Arts on teams that design**,** develop and manufacture a variety of "prototype products" with corporate sponsors. Berrisford is also a nationally recognized visual / installation artist and curator who has exhibited nationally and internationally. He is currently represented in New York City by June Kelly gallery and in Philadelphia by The Sande Webster gallery. Over his ten-year tenure at Lehigh he has had seven one-man exhibitions and participated in excess of 40 group exhibitions nationwide.