A FACILITY TO FACILITATE ENGINEERING DESIGN & ENTREPRENEURSHIP CURRICULUM

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Abstract**—***At Penn State University there is a greater emphasis on engineering design and engineering entrepreneurship courses in the first two years of the engineering programs. These courses need general-purpose design facility, where the necessary tools for collaboration, design, construction, and testing are made available. In these programs students are working in design teams some of which are international teams. In the entrepreneurship courses the faculty work collaboratively with Colleges of Business to introduce modern business skills as an integral part of engineering design curriculum. These initiatives are based on a common theme of engaging students in cross-disciplinary problem-based learning opportunities in the context of industry sponsored engineering design projects. The curriculum needed to support these initiatives has been under development since the early 1990's. To support this curricular need a physical space is developed. This facility has evolved from various forms through out the many decades to support the curricular innovations.*

Index Terms – Engineering Design, Entrepreneurship, Instructional Facility, Flexible Classroom

INTRODUCTION

As the College of Engineering at Penn State implements changes to achieve it's goal of educating World-class Engineers, more and more design experience is being incorporated into the curricula of various departments. A critical part of the World-class Engineer model is related to professional skills, such as modern business skills, team skills, communication skills, and an understanding of the impact of engineering design in a global context. To place greater emphasis on the modern business skills, with the support of GE Learning Excellence Fund, the College has developed an engineering entrepreneurship program[1]. This program is developing engineering undergraduate courses that incorporate product conceptualization, design, technical feasibility, and market opportunity in a collaborative, interdisciplinary setting. The courses and programs are developed in collaboration with the Smeal College of Business at Penn State – University Park, the Penn State Altoona Division of Engineering and Business, and the local entrepreneurs.

The World-class Engineering concept also involves students working collaboratively with other international students on industry sponsored projects. The industry sponsorship can also be local or international. This initiative was developed with the support provided by Alcoa, and have been integrated in the first-year honors version of the introductory design course [2][3]. More recently these efforts are also funded by US Department of Education as the Fund for Improvement of Post Secondary Education (FIPSE) [4].

CHANGE IN STUDENT ACTIVITIES

To understand the impact of integrating engineering design activities in introductory courses, we studied the past course schedules and examined the class-time student activities for a the first-year design course [5] offered at Penn State University. This course has evolved from being a drafting course to an introductory design course over the last three decades. We examined the class schedule over the last three decade and compiled the student activities in five major categories: (1) lab experimental work, (2) computer tools, (3) building prototypes, (4) design collaboration, (5) engineering drawings. *Lab experiments* primarily involved gathering and analyzing data to understand the behavior of engineering systems. *Computer tools* have evolved over time to include programming, analysis tools, CAD tools, communications tools (word processing and presentation) and more recently internet tools (collaboration and information access). The *building prototype* category is associated with building physical artifacts to support design concepts. *Design collaboration* involves students working in teams on design methods, design analysis, project management with mentors and resources in the classroom, or in a geographically dispersed team environment. *Engineering drawing* involves expression and documentation of design concepts in graphical format on paper.

The data plotted in Figure 1 illustrates the changing student activities over the last three decades in comparison to the year 2000. The study illustrates that engineering drawing decreased significantly over the years, while design collaboration, building prototype, and computer tools categories increased significantly. The lab experiments category stayed stable since the 1980's. Engineering drawing decreased from 100% to 22% of the class time from 1970's to 2000. During the 1970's introductory engineering courses primarily involved engineering drawing, and all other forms of student activities were nonexistent. By the 1980's the lab experiments and computer tools gained greater importance, and the emphasis on the engineering drawing began to decrease. Students were encouraged to

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work in groups. These were primarily group activities due to limited experimental setups. Students worked in groups to conduct the experiments and did the analyses and reports individually. By the 1990's, design projects began to emerge in the curriculum. The design based curriculum required greater integration among the five categories: lab experimental work, computer tools, building prototypes, design collaboration, and engineering drawings. By the late 1990's and early 2000 the five categories became far more integrated than ever before. The computer tools were needed almost 56% of the class time, and design collaboration was used almost 44% of the time.

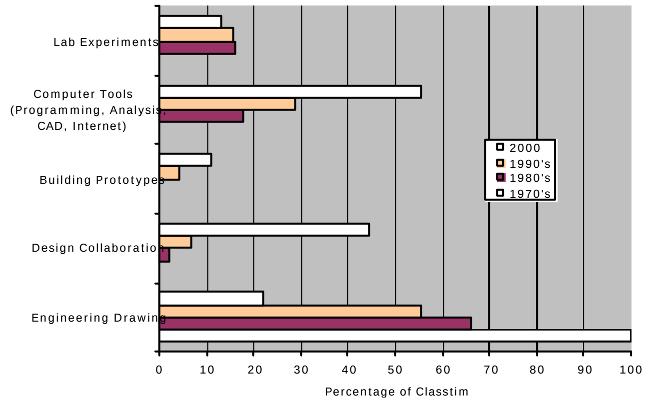

FIGURE. 1
STUDENT ACTIVITY IN INTRODUCTORY ENGINEERING COURSE

In the late 1970's and early 1980's, laboratory experiments in the engineering curriculum became an important part of the curriculum and therefore the emphasis on engineering graphics began to decrease. Also, during this time exposure to computer aided drafting and programming became important. Hence, some of the drafting classrooms and furniture, that existed since late 1890's through 1970's (Figure 2), were converted to computer classrooms and laboratories for engineering experiments. Therefore, during the early 1980s the introductory engineering curriculum, for example, used three types of classrooms for the courses.

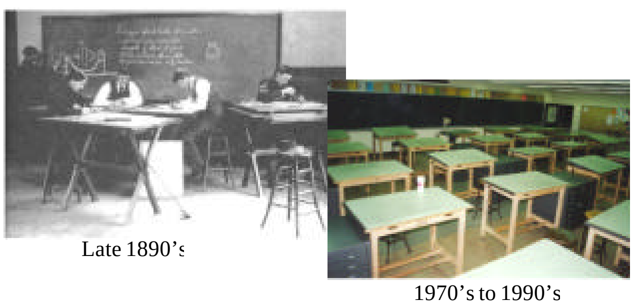

FIGURE. 2
ENGINEERING GRAPHICS CLASSROOMS 1890-1990 [6][7]

Each of the classroom was dedicated to one type of activity, such as conducting engineering drawings, computer work, or engineering experiments.

In the mid 1990's computer classrooms became more sophisticated and far more powerful than ever before. During this time design became the main focus of the curriculum largely due the NSF sponsored ECSEL initiatives [8]. The computer classroom reflected these changes by incorporating software tools to support design activity. The experimental labs were converted to Design Studios. By late 1990's the design curriculum began to include industry sponsored projects. These projects needed expanded general purpose design facilities to support them. Therefore, a model shop was added to the design studio to expand the capabilities of the design facility.

The resources needed for design collaboration also began to involve significant computer tools. Therefore, courses needing extensive design collaboration needed access to facilities that could support computer tools. Dedicated rooms for specific activities were becoming less functional.

To support the dramatic increase in the computer tools, the technologies needed to support design collaboration, and the physical space needed for team activities, a hybrid solution between the computer classrooms and the traditional classrooms began to emerge. This convergence led to the development of flexible classrooms. The flexible classroom provides the physical space and technologies needed for collaboration as well as the computer technologies needed for the various design activities.

To support the demands on the collaborative design curriculum a new Center for Engineering Design and Entrepreneurship (CEDE) was developed [9]. This facility constitutes the four types of instructional facilities: a) flexible classroom, b) computer classroom, c) design studios, and d) model shop.

CEDE – A FACILITY FOR COLLABORATIVE DESIGN

The CEDE facility includes 8 rooms dedicated to providing computer-based design tools, hands-on design and model building facilities, flexible meeting space, and voice/video/data conferencing capabilities. It is in immediate proximity to the Engineering Library where students can access special resources for their design projects. The Center is used by all first-year engineering students, and most of the sophomore level students. In addition, upper division students in Mechanical, Civil, and Aerospace Engineering and Engineering Mechanics are heavy users of the facilities. The total number of students using the facility exceeds 2000 per year. The following sections provide a detailed description of the facility, their potential use, and some of the advantages and disadvantages of the facilities.

Flexible Classroom

At many institutions there is a growing need to optimize existing use of classroom space. With increasing emphasis on teamwork, collaborative learning, hands-on activities, and greater use of technology in design and entrepreneurship courses, classes need many different types of rooms or a flexible space that can accommodate these different needs. There are three flexible classrooms in the CEDE facility. These classrooms are designed to provide hands-on learning environment where there are opportunities to conduct team work activities, collaborative learning activities, and have access to computer technology tools. The classrooms have access to wireless laptops (Figure 3), which are stored in a moveable cart. The wireless computer network provides full access to internet and university network drives. All software tools used in the courses are directly loaded on to the laptops.

FIGURE. 3
FLEXIBLE CLASSROOM ARRANGEMENT

The network is primarily used for data access and authentication. The classroom is equipped with moveable furniture to accommodate flexible arrangement for various types of uses. The data projection capabilities are made available through wireless keyboard and mouse to keep the middle of the classroom free of computer hardware. This arrangement has great potential as future replacement for computer classrooms. The benefits of this arrangement is the efficient use of the floor space and the flexible use of the technology. The challenges to this configuration are the maintenance and security of the hardware. Maintenance is challenging since the laptop parts are not as convenient to service and replace as desktop or tower PCs. Security is a concern considering the portability of the units, however these can be overcome by adopting simple procedures. Considering the reduced amount of overhead cost needed to deploy the technology in terms of network wiring, power, security, and air conditioning, there is considerable advantages that needs to be considered. The wireless cart solution can be deployed in multiple rooms with minimum overhead.

In the introductory entrepreneurship course where students are learning the business basics, the students get the opportunity to assess and study current market trends and analyze market performance data in real-time, which adds richness to the classroom experience. The laptop environment seems to be conducive to discussion mode, where face-to-face dialogues are preferred, and the computer technology is viewed as non-distracting. In the introductory architectural engineering design course the same classroom can be transformed to a drafting facility (Figure 3) with portable drawing boards with T-square. The portable boards are stored in a cabinet and students help themselves to these tools, just as they do with the laptops.

Computer Classroom

The computer classrooms are designed for interactive computer based instruction. In this environment each student has direct access to a secure computing environment and is able to follow instructions provided by the instructor at a podium station, where the podium computer image is projected on a large screen.

FIGURE. 4
COMPUTER CLASSROOM ARRANGEMENT

This arrangement is typical to most computer classroom facilities. The unique feature of this facility is the ability to cluster student teams in the classroom. Each team of four students are seated together to encourage collaboration and build a sense of team identity. There are two computer classrooms in the center. Each classroom contains 36 PCs and a small number of UNIX workstations. Both rooms provide video and data projection capabilities. The center is supported by a dedicated 100Mbit/sec network to the university backbone. The classroom provides video conferencing capabilities using PictureTel via both IP and ISDN connections. Some of the generic design software provided in the classroom include ProEngineer®, ProMechnica®, SolidWorks®, IDEAS®, ABAQUS®, ANSYS®, Unigraphics®, IronCAD®, and SolidEdge®. Several course specific software are made available as needed for the specific courses. The classroom also provides conference telephone and fax machines as collaboration tools. Light controls are available to enhance the lighting for various types of presentations.

The computer classroom facilitates both instruction and collaboration. Instructional use in this environment is well understood, where faculty is guiding the students with specific techniques or tools. In the collaboration mode the students can use the technologies available in the room to work with others anywhere in the world via IP or ISDN using voice, video, and data. These technologies are used in the first-year honors version of the design course, where students collaborate on industry sponsored design projects with Université d'Artois in France [2] and University of Leeds in UK. Students can collaborate on design projects as individual teams using the small PC camera and the NetMeeting tools over IP, or engage in a larger class discussion using the room PictureTel system. Providing technologies for this type of collaboration is not the challenge. The true challenge is integrating these tools in the curriculum in such a manner that the students use them effectively to accomplish the goals of the design task.

Design Studios

The design studio is a facility for student teams to perform assembly and disassembly of products, conduct performance tests of products and processes, and conduct basic engineering experiments. The facility is equipped with workbenches, hand tools, measurement and test-equipment. The hand tools include a suite of tools that can be used to

FIGURE. 5
DESIGN STUDIO ARRANGEMENTS

take apart and rebuild products such as single cylinder engines, bicycles, small toys, and household products. The measurement and test equipment include oscilloscopes, spectrum analyzers, data acquisition units, multi-meters, power supplies, function generators and other related equipment. This facility also has access to wireless laptop computers and PC stations to performs data-acquisition and analysis using software such as LabView®.

First-year engineering students use the facility to build working prototypes of their design projects. Some first-year design projects involve designing electronic weighing systems using strain gages and beams, temperature controllers using Basic Stamp II microcontrollers, or building various other types of prototypes as needed for the course. In many of the First-Year seminar courses [10], the facility is used by students to take apart and rebuild single cylinder engines, redesign bicycles, building loudspeakers, redesigning robotic toys, and for other similar activities. The upper level courses use the facility to build and prototype products as related to the entrepreneurship program. These products may include cigarette-dispensing machines, mobile entertainment and GPS system for cars, and any other products the students launch as part of the entrepreneurship program.

Model Shop

The model shop is a light construction facility to support some of the construction needs for the design studios. The shop contains basis power tools such as drill presses, various types of table saws, sanders, routers, and many different types of powered hand tools. The shop can support light wood and plastic material construction.

FIGURE. 6
MODEL SHOP ARRANGEMENT

The facility is only accessible to students who have been certified to use the equipment. Faculty and students using the facility need to pass a competency test of building a product to specification that requires the use of various tools in the shop. Supervision, training, and safety are key to this type of facility. The model shop by itself does not have an extended function. However, in conjunction with the studios, the shop extends the prototyping capabilities of the Center. The Center works closely with the Learning Factory, which provides extended manufacturing tools such as machining, welding, rapid prototyping, and expertise in building finished products.

STUDENTS AS AGENTS OF CHANGE

Since the inception the computer classrooms and experimental labs in the early 1980's, students have played an active role in the facility. Initially, undergraduate students were hired on a part-time basis to help run the lab sessions. Very soon after the faculty and administrators realized the value of highly motivated, highly talented undergraduate students working in these environments, and students got greater responsibilities in these facilities. Soon students were trusted with leadership roles in experimenting with new techniques and strategies in the classrooms. By the early 1990's a team of students were the primary staff responsible for the day-to-day operation of the classroom facilities under the supervision of one faculty. These students were organized in a structure such that the more experienced students could train the new hires. Students started working in the facilities as early as the first-year and many would work in the facility until their graduation.

As computer technology became more sophisticated in the mid 1990's, the student staff also became more talented in their computer technology skills. Students embraced the changing technology with far more enthusiasm than many of the senior staff, and hence the student played an even larger role in the deployment of technology enhancements for the learning environment. Today, a dedicated team of 5 students manage the entire computer technology needs of the 12,000 ft^2 facility. The facility contains over 180 computers on a dedicated 100 Mbit/s subnet. The student staff administer and maintain the entire network including the client hardware and software related to the facility, data storage, authentication, and security. Student staff work with the faculty to implement special software and hardware needs specific to courses. In fact, the wireless computing environment for the flexible classroom was developed and deployed by the student team.

Just as in the computer technology, a small staff of students also lead the design studios and the model shop. A team of 4 students manage the two design studios and the model shop. These students are responsible for the day-to-day operation of the facility to ensure that the equipment is in safe working order to meet the needs of the users.

The rapid changes in the facilities over the years, leading to the creation of the CEDE is in large part driven by the student enthusiasm. Their active involvement not only allowed the new developments, but also the integration of the new tools into the curriculum. The proactive involvements will continue to grow, and they are our agents of change to explore new techniques and tools for the learning environment.

SUMMARY

The current classroom facilities have evolved over a period of two decades. The development of the Center has given the ongoing curricular developments in the last decade an endorsement of achievement. As developments in the curriculum evolve, the facilities will change. When new facilities are put in place the curriculum becomes institutionalized. The need for design studios and model shops will continue to grow as more courses embrace active, collaborative, cross-disciplinary design activities. The tools available in these facilities will also grow. The facility is becoming a gathering place for students, faculty from colleges of engineering and business, industry, and local entrepreneurs involved in learning experiences. The collaborations that take place here will strengthen the engineering student experience in the years ahead.

The flexible classrooms are here to stay and will grow very rapidly, since it optimizes the use of physical space. The computer classrooms, a dedicated space for computer use, will diminish in value with the expansion of flexible classroom. With wide spread access to computer technology, computers will become just another tool, and far more integrated into the learning process and the environment.

The largest anticipated future growth is the collaboration between *engineering research* activities and the *engineering design* activities as related to curriculum. This collaboration will have significant impact on the education facilities. This is a challenging notion, since a large part of the research activities take place at the graduate level, and design activities are largely viewed as undergraduate activities. However, with the inclusion of entrepreneurship with design, there are greater opportunities to consider links between marketable design activities and engineering research activities. If these curricular links do take place, there will be significant enhancements between general purpose design facilities and access to discipline specific research facilities. This will translate to better integration of research facilities and instructional facilities. For this integration to take place research and collaborative design must become an integral part of student educational experience.

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