Introducing Design Throughout the Curriculum

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Abstract

Polytechnic University has embarked on a major effort to introduce Engineering design across its entire curricula. This effort is across all majors and affects essentially every course. There are several features at its core:

1. A 4-credit course in Freshman Engineering that introduces students to software and hardware tools, teamwork, written and verbal communication skills, project management, as well as overview lectures on major technical and non-technical disciplines.

2. Creation of a large, interdisciplinary undergraduate laboratory, used by students from many disciplines to plan a variety of engineering experiments in a common space.

3. Use of laptop computers as design tools that are integrated into the Engineering courses.

I. Introduction

Our world is becoming ever more complex. It is no longer possible to cope by relying on expertise from a single discipline. Concurrent Engineering is now a practice used throughout industry, and its participants are expected to be able to work in an inter-disciplinary environment. A second trend is the renewed emphasis on design, as opposed to analysis, in Engineering. This leads to a requirement for engineering curricula to emphasize design and interdisciplinary thinking from the very start. Freshmen in engineering schools must come aboard the "speeding train of runaway information overload" and be able to sort out what is and what is not relevant. They must be able to work in multi-disciplinary teams and be able to present their activities to peers as well as supervisors. To this end Polytechnic University teaches EG1004, Introduction to Engineering and Design, a course that provides freshman students with an overall perspective on engineering and with useful tools and work methods that will be of great utility to the students in the years to come. This also leads to a requirement for interdisciplinary labs and for providing the proper tools to the students to encourage design efforts.

II. Background to EG1004, Introduction to Engineering and Design

EG1004 consists of lectures (1 hr/wk), laboratory work (3 hrs/wk), and recitations (2 hrs/wk) for an academic semester. Activities and examples from a variety of engineering disciplines are presented, and a selection of professional tools (MS Word, MS Excel, MS PowerPoint, MS Project, AutoCAD, LabView) is introduced. Students are exposed to team building activities and must make presentations (both written and oral) as an individual and as a member of a team.

Laboratory work involves design competitions and the students must select one of several different semester-long design projects that require teamwork and develop project management skills.

The class is unique in that it primarily uses undergraduate teaching assistants (TAs) for the laboratory supervision (See ref. 1). The technical faculty and technical writing consultants, together with the TAs, run the recitations and semester projects. Invited speakers who are specialists in their various fields give lectures weekly.

The class recitations consist of presentations of lab activities (MS PowerPoint) to their peers, and submission of electronic/paper lab reports. Periodically a project progress report is given. All these activities are graded and the students get immediate feedback about their performance. Technical writing specialists from the Humanities department act as writing consultants, playing a crucial role to help improve both the written and oral presentation skills of the students.

III. Overview of Course Content and Goals

Lectures are given weekly by experts in the fields and vary somewhat from semester to semester. Typical lecture topics are:

- Introduction to Course / Engineering Disciplines
- Robotics
- Safety & Reliability
- Large Software Projects
- Civil Infrastructure
- Aerospace, Apollo, and the Lunar Module
- Design for Manufacturing
- Chemical Technology & History
- Signal Processing
- Ethics in Engineering
- Quality Management
- Intellectual Property

Laboratory work covers many disciplines. The undergraduate teaching assistants help freshmen get familiar with new technical tools and concepts. The primary weekly laboratory activities cover:

- Word/Excel/PowerPoint
- AutoCAD/MS Project
- Hardware Tests
- Hardware Analysis/ Reverse Engineering
- Boom Construction Competition
- LabView 1
- LabView 2 / Sensors and Robot Programming
- Thermal Insulation Competition
- Microphone

- Filters
- Communication
- Digital Logic

IV. Semester Design Projects

Students in EG1004 must complete a semester-long design project. This is a 12-week team project done by groups of two or three students. It requires selection of one of the projects, presentation of a preliminary design, planning the project schedule, making periodic progress reports, preparing engineering drawings, building a working model of the design utilizing required software programming, and a final "sales presentation" where the student teams compete against each other to "make the sale". Minimal design is encouraged; i.e., minimum cost, minimum time, or the fewest parts and the least amount of programming to do the task.

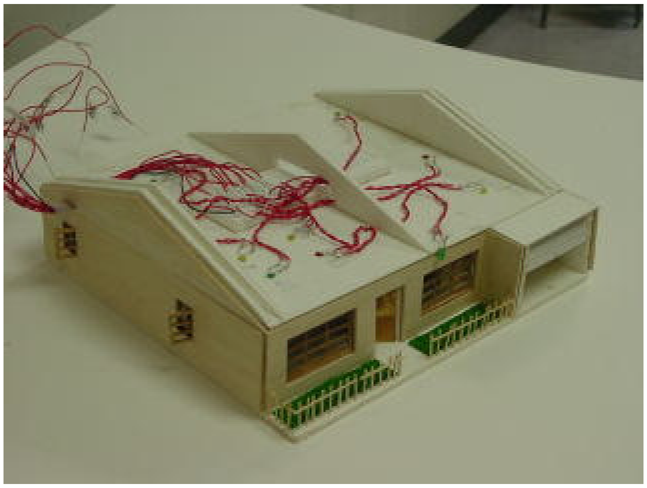
Two of thedesign projects are described below:

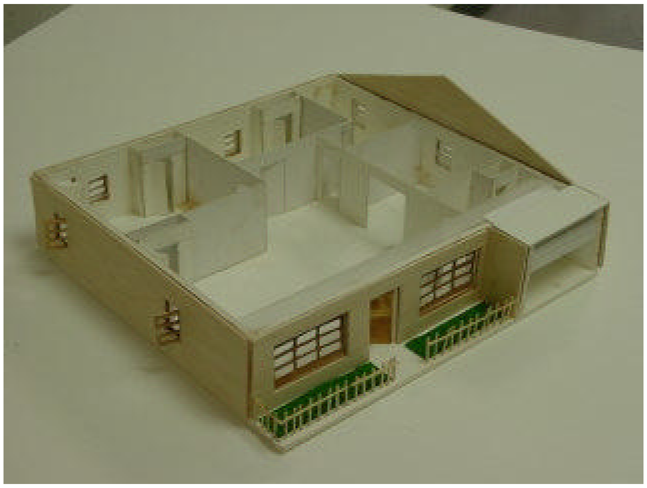
- House Design Project
- Robot Design Project

V. House Design Project

This project calls for the design of a single-story house using AutoCAD and MS Project. At the completion of the design period, the design team is to build a model of the design, using the materials provided to the specified scale. The team also implements a LabVIEW program that controls the lighting and temperature controls in the house. The project is to be completed over 12 weeks. The project includes at least 6 drawings as well as the model of the design with implementation of the LabVIEW program. The project is a team effort, i.e. done by groups of two or three students.

The ground rules for the house design project are included on the Freshman Engineering Web Site (see Bibliography). Photos of typical student house designs are shown below.





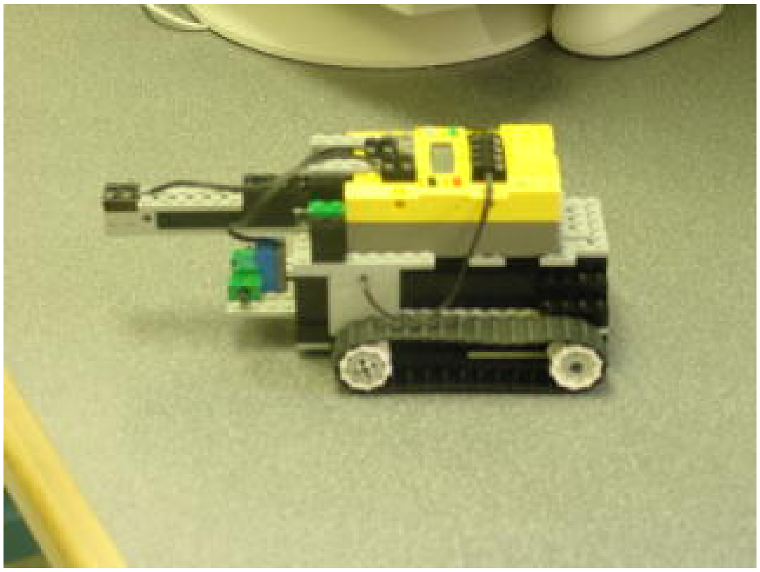
Photos of two house designs

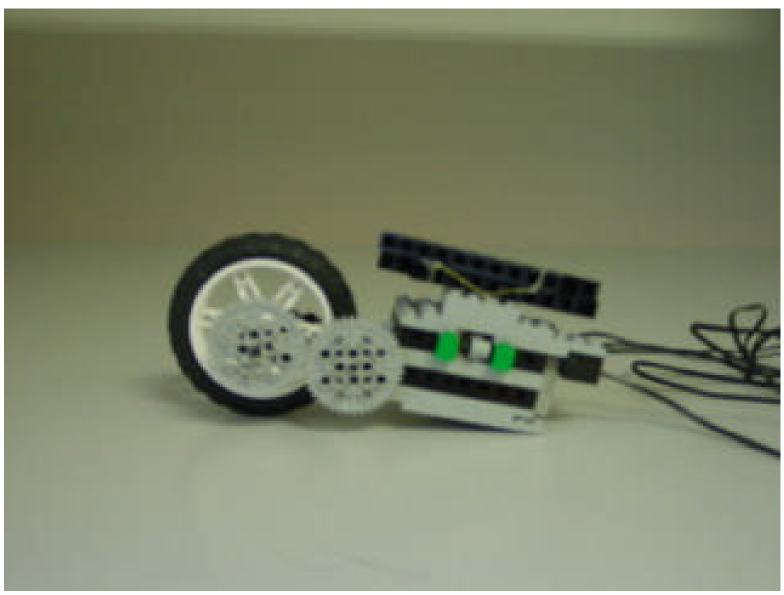
VI. Robot Design Project

For this project the team will bid on a contract for the Unites States Federal Bureau of Investigation. This contract calls for the design of a robot or vehicle that is able to navigate an obstacle course. The robot will be made from parts sourced from Robolab kits and be built according to a project plan. Upon completion of this project the group will have designed a robot according to the specifications given below, and presented a budget estimate, project plan, and full two-dimensional drawings to the customer. The group will also have built a model of the robot and competed against other groups for the production contract.

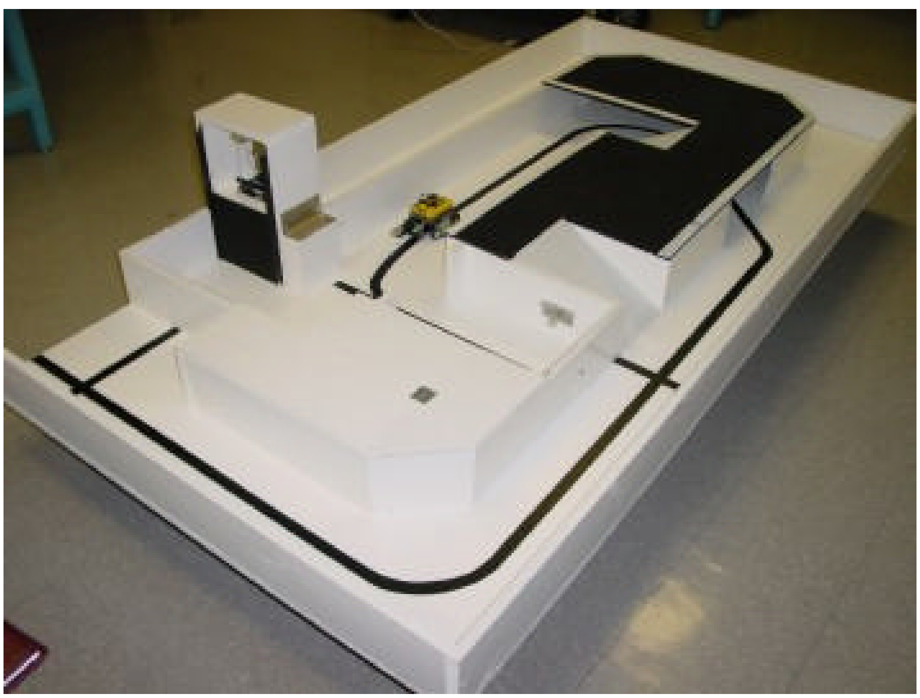
Students will learn about uncertainties in design: variation in battery power, traction, motor speeds, sensors, and pressure connections (fitted assemblies allow faster construction but increase tolerances and are not as solid as other fastening methods). Software logic will have to include frequent reassessments as to where the robot is and will compensate for the mechanical tolerances.

The ground rules for the robot design project are included on the Freshman Engineering Web site (see Bibliography). Photos of two robot designs and photos of the obstacle course are shown below.





Photos of two robots



Photos of obstacle course to be traversed by robot

Videos of robot solutions can be found at http://eg.poly.edu/Robotvideos/

VII. Interdisciplinary Laboratory

As the result of a major bequest and a highly successful comprehensive fund-raising campaign, Polytechnic University has completely revamped essentially all of its undergraduate laboratories.

As part of the renovations an "Interdisciplinary ME/CE/ChE Lab" was constructed to encourage faculty and students to see both underlying commonalities and different ways of applying concepts and tools. Fluids and heat transfer are in one area, structures in another. Electronic microscopy --- common in ME --- is available for experiments in the other disciplines, as one example of opportunity. While there are still traditional "soils" experiments, it is also true that many more experiments are based on precision work and --- to a growing extent --- on micro scale and on bio-related applications.

To date, true interdisciplinary use has been slow, but we are only one year into the use of the facility. Faculty and departments are now actively discussing joint experiments, encouraged in part by a capital allocation policy that is entering its second phase (basics first, then more real integration). The question of "Who is in charge?" relating to technician assignments and lab security (open hours, use of equipment) is a practical and real issue. We are moving ahead under the premise that more real use --- senior projects, and so forth --- will actually alleviate some initial concerns over "ownership".

In addition to refreshing the equipment in the traditional laboratories such as electrical and mechanical engineering, the University has also constructed a new interdisciplinary laboratory that occupies most of the fourth floor of its main building, Rogers Hall. The equipment in this laboratory supports all the engineering disciplines, and is used to support multiple laboratory sessions simultaneously. Many experiments are being modified so that students from several majors must work on the same laboratory exercise as a team. This teaches them how to work in an inter-disciplinary environment. This reinforces the skills the students learned in Freshman Engineering, and gives them increased depth in working in teams.

Part of the University's upgraded laboratory effort is the construction of a new building, with the majority of the space in this new building being used for laboratories. In addition to giving Freshman Engineering substantially more space and better accommodations, it will also house a new Prototype Laboratory. In this laboratory students will have access to a wide variety of machine tools and other equipment to allow the construction of an extensive range of projects. We expect many of these projects to be inter-disciplinary in nature, involving at least three different majors in the development of various projects. By design the Prototype Laboratory will be one large room where several teams can be working simultaneously learning from each other.

VIII. Laptop Computing

We found that a major barrier to supporting our design and inter-disciplinary initiatives was our Information Technology infrastructure. The University has the usual computing laboratories primarily supporting our freshman programming courses which are mandatory for all majors. The University also has a variety of other laboratories supporting specific missions. For example, Freshman Engineering had its own computing technology integrated into its laboratory rooms. The result was that although each laboratory had an extensive repertoire of software, it was not unusual for students to have to visit several computing laboratories to perform their class work and projects. We felt that this detracted from the unified environment they should be experiencing. As a result, laptop computers are now required of all students, starting with the freshman class that was admitted for the Fall 2000 term.

These laptops contain software under the University's site licenses and will support almost all their computing needs. The complement of software includes the entire Microsoft Office suite, Microsoft Visual Studio, Borland C++ Builder, Labview, Common Space, MatLab, AutoCAD, Robolab, and much more. The laptops are at the high end of performance when they are distributed, and include a DVD/CD drive as well as 100Mb/S wired Ethernet as well as a wireless LAN card. This means that the students see a consistent set of tools used across all their courses. Although the University was ranked number 75 in the "100 most wired schools" in 1999, we have found that the use of wireless technology has made fundamental changes in the way students work. Students still make use of the wired LAN when they are transferring large amounts of data (for example, MPEG files they've created), but they prefer the convenience of the wireless LAN for most of their work. With the wireless LAN students can work anywhere they want. For example, for the house design discussed earlier, in past years the students would have had to work in the Freshman Engineering Laboratory during times that classes were not in session. Now they can design on their laptops and their team can work wherever and whenever they want. Similarly, for the robot design project, they could build the robot and program it anywhere allowing them to come into the Freshman Engineering lab sessions with work already underway. The use of wireless technology allows them to easily share data reinforcing their experience in working in teams.

The resident students have wired Ethernet jacks in their rooms, one jack per bed, as well as coverage from the wireless LAN. Commuting students have access to the University computing complex via these LANs when they are on campus and via dialup lines, ISDN, and access through their own Internet Service Provider (ISP) when they are home. This last alternative is becoming increasingly important as DSL and cable TV modem technology continues to grow. Overall, we are finding that our students are making heavy use of this connectivity in their course work. One example of this is that our heaviest network usage is usually from 1-2AM.

IX. Student Feedback & Comments

The University has an Office of Assessment to aid in getting student feedback in our courses. Overall, our improvements have been favorably received. For Freshman Engineering student feedback is solicited in both optional and mandatory surveys conducted during the semester. A majority of students preferred the robot project. They were allowed to take the Robolab kit with all components home and were able to do testing and programming using their laptop computers. Thus they only had to come to the lab when they tested their design in the obstacle course. They were also pleased to see the use of interdisciplinary activity through projects such as the robot, which required a number of different skills. Overall, the student evaluations of Freshman Engineering were notably higher than in past years.

All this increased use of technology has not been an unmixed blessing. One of our surveys showed that with some students, the use of laptop technology was a distraction, where they would be using Instant Messaging with their friends during classes, or would be busy downloading MP3 files or surfing the Internet during lectures. Similarly, one problem with the robot designs is that it could become addictive. Some students became totally enthralled with the mechanical/sensor/software aspects of the designs and spent significant amounts of time on the project to the detriment of their other courses. We found that we have had to provide much more guidance on time management and study habits than past years. In spite of all this, we still strongly believe that overall the students have been well served by all these technologies.

X. Summary

This paper has outlined some of the recent technology initiatives taken by Polytechnic University. We are implementing the "design across the curriculum" concept starting with Freshman Engineering, and ending with their Senior capstone design courses. Through the use of projects within courses such as the design of a house or a robot, we are introducing students to the methodology of working in inter-disciplinary teams from the beginning of their studies. The use of laptop computers and both wired and wireless technology is an important enabler of these initiatives. We expect to continue to evolve in the years to come.

Acknowledgments:

The authors would like to acknowledge the many people who have helped make this class a success: instructors, teaching assistants, and dedicated students --- both current and from previous years.

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