A "Real-Life" Interdisciplinary Capstone Design Course.

Henry Chaya, Graham Walker
Manhattan College
Riverdale, New York

Abstract

A new interdisciplinary design course has been developed. A unique feature of this course is the participation of alumni who have been involved with engineering practice for a number of years. These alumni assume the role of clients for the design project. Their involvement added unique insights to the real practice of engineering design. It also greatly enhanced student interest in the course.

I. Introduction

At Manhattan College each department in the School of Engineering has a group of advisors we call the "consultors". These are men and women with years of experience working in the field of engineering who volunteer their time to help the departments plan appropriate educational programs. Often they are alumni who are familiar with the mission and objectives of the College.

During the fall semester of 1999, there were a series of meetings between several faculty members of the department of Electrical and Computer Engineering, ECE, and their consultors. The purpose of the meetings was to discuss the objectives and implementation of capstone design courses in the undergraduate curriculum. We also discussed ways in which the consultors could assist directly in the capstone design courses.

The ECE faculty are all experienced teachers who are very knowledgeable about technical subjects. However, they have limited recent experience working in industry, and we recognized there have been significant changes in the way engineering design is practiced. For example, today an engineer usually works as part on an interdisciplinary team rather than alone, and he or she must be more aware of the economic, social and ethical realities that constrain an engineering solution. Consequently, we decided that the consultors could assist the faculty by playing the role of clients for a design project, thereby providing a practical flavor to the course. As clients the consultors would ask students to prepare proposals, reports and presentations as is done for their own clients. The consultors would not need to be expert in the technical aspects of the design, but they could raise questions about project schedules, costs and quality assurance, which might not occur to faculty or students.

We decided to ask two consultors to participate in one of the three design courses offered by the ECE department during the spring 2000 semester. This was an interdisciplinary course on robotics and automation offered jointly by the Mechanical Engineering department and the ECE department. The instructors of that course are the authors of the present paper.

II. Course Overview

A central goal of the course presented here was to permit students from both departments to work on an interdisciplinary design project. The emphasis was on teamwork, since the project required a breath of skills no individual student possessed.

Students were asked to design, build and test a robotic manipulator system to determine the edges of an arbitrary flat two-dimensional object. The system had to automatically locate the edges of the object and display the contour as a graphic on a computer monitor, and a two-axis manipulator had to retrace the contour with a specified accuracy and speed. Consequently, the device would be suitable for cutting shapes from sheet metal or fabric.

The students were also required to design software with a graphical-user interface that was easy and intuitive to use. Finally, they were asked to organize the software with an application programmer's interface that would facilitate software development by the customer.

Deliverables due at the end of the course were:

1) One prototype manipulator with documented tests to prove that it met specifications.
2) A complete set of software including source code and user documentation.
3) A presentation discussing the purpose, operation and specifications of the system.
4) A report describing the overall design of the system, and its basic theory of operation. (The report had to include mechanical drawings, schematic diagrams, a parts list and a cost analysis for mass production of the system.)

Students were given a budget of $1000 to development the system, but the per-unit cost for manufacturing the device was to be under $500.

III. Role of the Consultants in the Design Course

Two months before the course started, the instructors wrote a "request for volunteers" which was sent to all members of the consultor group. In this document, we defined the role of the volunteer consultants so that they could understand the nature and scope of the commitment. Then we met with two volunteers before the semester began to agree on design criteria for the project and to set deadlines for reports and presentations. The volunteer "clients" would also formally evaluate student work at three points during the course: the initial proposal, a mid-project review and a final presentation. In addition, students would be allowed to communicate directly with the "clients" to ask or answer questions about the design.

The volunteers and instructors met a week before the start of the semester, to review the design criteria and spell out the expectations for the initial proposal (due the second week of the course) and the mid-term presentation. The clients came to campus for the mid-term presentation to review progress to date. Specific expectations for the final presentation were then formulated after this review. We considered having the final presentation off-campus in front of a larger group of "clients", but as it turned out the two volunteers came to campus during the last week of the semester.

At the initial meeting, we also discussed the appropriate forms of interaction between clients and students. This relationship would be strictly formal dealing only with design issues. Any issues relating to the course such as grades or other personal difficulties were to be referred to the instructors, since we felt that it was be inappropriate for a consultor to assume the role of advisor.

IV. Course Organization and Grading

The class was scheduled to meet twice a week for 90 minutes. The first two meetings were devoted to introducing the design project and reviewing the resources available. We also discussed design tools such as Gantt charts and design matrices. After the first week, the students lead the class meetings by setting agendas and chairing meetings. The lab space devoted to the course was available at any time, and it had a conference table that facilitated team meetings. There were no scheduled lectures, but instructors were available for instruction on technical content at the request of the students.

The eleven students organized themselves into four teams: software, mechanical systems, motion control, and sensors/instrumentation. Each student served on two teams except for the project leader, who was associated with only one team. Serving on multiple teams helped promote communication among the various teams. Each team was required to submit a brief biweekly report, and each student was asked to keep an individual logbook. The team reports were submitted to the instructors and the other team leaders, while logbooks were reviewed periodically by the instructors.

The entire group prepared the initial proposal, which explained to the clients how the students would develop a solution to the design problem. This proposal included a discussion of team organization, a project timeline and a budget. They also prepared the midterm review and final presentation for the clients as a single group. The written report and software documentation listed in the deliverables was submitted to the instructors, but it was not completed in time for review by the clients.

Grading for the course was based on all the presentations, reports and logbooks mentioned above plus a peer evaluation conducted at the end of the semester and the instructors evaluation of individual performance.

V. Observations on the Conduct of the Course

Once the initial introductory classes were completed, the students "took ownership" of the course. They were eager to implement their own ideas to show that they were able to employ the engineering skills that they had learned over the previous four years. Consequently, the instructors merely assumed the role of advisors and technical consultants.

This point was best illustrated in the case of the method used to acquire an object's contour. The instructors expected the students to develop a tactile system; however, they devised an innovative solution that employed an inexpensive scanner. This fact enhanced student enthusiasm for the course.

Some instructor intervention was necessary to resolve certain group dynamic problems that existed within the teams. For example, one student who led the software group was an experienced programmer in C++. Consequently, he wanted to do the entire project in that language, however the rest of the students were more familiar with Visual Basic and wanted to use that language. The instructors intervened to resolve this disagreement by discussing the importance of allowing all members of the team to contribute to the project.

At another intervention occurred when groups began to duplicate their efforts due to poor communications among the teams. Furthermore, some students were missing meetings too frequently. The instructors therefore found it necessary to call a meeting to bring the project back on track and discuss the importance of teamwork.

On other occasions, the instructors felt in necessary to point out the relevancy of applying theory to the problem, rather than merely blindly applying a solution and then testing the result. For example, students did not appreciate the ideas learned in control theory when they tried to tune the PID servo controllers.

Finally, by the end of the course, the students had a working prototype, which would require significant refinements for it to be considered marketable. However, the students gave a good assessment of the final design, performance characteristics, and shortcomings of the device during the final presentation. It should be noted that one of the clients commented about the high degree of teamwork that was evident in the presentation.

The interaction with the "clients" proved to be trouble-free and productive. During the initial stage of the project, the clients had several questions about the initial proposal, and students responded appropriately to these by email. Then, at the midterm presentation the clients asked students to develop specific tests to determine if the prototype meet specifications. The clients also raised issues about the cost of manufacturing the units and technical support. The students addressed these issues in a timely manner. Finally, at the last presentation, the clients raised many challenging questions that the students were able to address immediately by presenting additional information or by recasting the information presented.

VI. Course Evaluation

After the final presentation, students completed a questionnaire with several open-ended questions. The instructors then reviewed these responses before engaging in an oral evaluation of the course with the students during the last day of class. The results of the questionnaire and the verbal discussion were summarized by the instructors and sent by email to the consultors who had served as clients. The consultors were asked to respond with their own evaluation and recommendations for the course.

One of the questions on the questionnaire asked students to describe their feelings about the interaction with our consultor/clients. Most students had very positive comments about this aspect of the course. It gave them valuable insights into how design projects were conducted in the real world. They also noted that the clients had raised important issues that they as students had not considered. In addition, several comments indicated that the positive feedback from the clients had given the students confidence to undertake such projects in the future.

During the class meeting, we devoted some attention to the interactions among students and instructors, time management and team participation. The students affirmed that the instructors should play the role of advisors. To paraphrase one student "Spend the first two weeks telling us exactly what you want, then leave us alone. We'll call you if we need advice." In addition, many students found working with others to be a challenge, and therefore some students wanted team meetings more frequently, a mandatory meeting once a week. Other students did not see a need for this.

The consultors evaluation of the course was that "the class came together well". Some of their comments were that they "saw dramatic growth in their ability to function as an integrated team," and that they were "impressed by the intensity and interest the students expressed in the work they were doing." Finally, one consultor noted that "the robot itself was impressive." Overall, the consultors felt that the course had accomplished its goal, and they strongly affirmed the value of their involvement in the course.

Finally, however, the two consultors both agreed that we could have done more to prepare the students to work as a team. They also suggested that we devote some time to discussing team dynamics and conducting effective meetings at the beginning of the course.

VII Conclusion

Both departments plan to offer this course again and to continue the involvement of consultors acting as clients. The instructors recommend that at least the first three weeks be devoted to formal instruction about the design process and team skills. We also suggest that there be a mandatory meeting of the teams at least once a week.

Henry Chaya

Henry Chaya is an Associate Professor of Electrical and Computer Engineering at Manhattan College in Riverdale New York. His professional interests include robotics and automation, artificial intelligence, embedded control and digital systems design. He has contributed extensively to the development of laboratory courses including design of custom hardware and software. Dr. Chaya has taught introductory programming courses for many years. Recently, He completed a term as chairman of the department. He received a BS degree from Manhattan College in 1973 and a Ph.D. from Princeton University in 1981. Dr Chaya is a member of the Brothers of the Christian Schools.

Graham Walker

Dr Walker is a Professor in the Mechanical Engineering at Manhattan College in Riverdale New York. Dr. Walker works in the area of system dynamics. His work has involved developing hardware and software that allow flexible manufacturing systems to operate more efficiently. In particular, he has been associated with the design of software to automate the selection and installation of machining fixtures, and the design of a vision system to obtain depth information in a manufacturing environment. In addition, his work has included research in the area of nonlinear control of robotic systems. At present, his work is in the area of biomechanics. This includes working in conjunction with the Orthodontic School at Montefiore Hospital to study the mechanics of tooth movement. He is also working in conjunction with the Pediatric Unit at Beth Israel Hospital on a research project associated with brain trauma.