Abstract - The ever increasing globalization of engineering practice has led to the realization that undergraduate students must be made aware of the global nature of the profession and the technologies that allow engineers the world over to collaborate on projects. To this end a pilot program called the “International Virtual Design Studio” (IVDS) was undertaken jointly by the departments of mechanical engineering at Union College in Schenectady, NY and the Middle East Technical University (METU) in Ankara, Turkey, wherein students from each institution are joined as a team to pursue their senior design projects across international boundaries and culture differences. Using a combination of interactive video and Internet communications, the two parts of the team undertook a single design and build project, sharing data bases and designs electronically, communicating both by e-mail and in real time through periodic video conferencing, and building their respective portions of the final design at the individual institutions. The team members met each other in person at the end of the project when they came together in Ankara to assemble the final design and participate in the design competition with the remaining teams from METU.

The IVDS provides students with a real-world design experience, international cultural interaction, and team building and project management experience. The success of this program has led to plans to expand it to include other disciplines and additional universities throughout the world.

Introduction

The engineering profession has evolved into a global enterprise in which engineers from several countries are often teamed on a single project [1,2]. An example that clearly illustrates this point is the International Space Station in which 13 countries (United States of America, Canada, Japan, Russia, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and Norway) are pooling manpower and resources to achieve a common goal [3]. International teaming is also the current practice in many multinational, high tech enterprises. The ever increasing globalization of engineering practice has led to the realization that the engineering curriculum must be restructured to provide students with an awareness of the global nature of the profession and some level of international experience integral to the undergraduate program.

The international component in engineering education is no longer up for debate. In the Accreditation Board for Engineering and Technology (ABET) Engineering Criteria 2000 [4], under program outcomes and assessments, one of the items that each engineering program must demonstrate is that their graduates have, “the broad education necessary to understand the impact of engineering solutions in a global/societal context.” The debate must now center on how this can be accomplished with the least amount of impact on engineering fundamentals in the curriculum. The approaches that are currently used to integrate an international component into an undergraduate education include terms abroad, exchange programs, and international terms in industry (or international co-ops) [5]. These options may not be financially possible for some students and the operation of such programs for all students may be beyond the practical reach of many institutions. An alternative is the International Virtual Design Studio (IVDS) which provides an international collaborative design experience for engineering students widely separated by time, geography, and culture through use of interactive video conferencing and electronic communication via the Internet.

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In the remainder of this paper the pilot IVDS project recently completed between Union College in Schenectady, NY and the Middle East Technical University, in Ankara, Turkey will be described. First a background history of how the concept for the IVDS project came about will be presented. This is followed by an overview of the pilot program structure, objectives, and equipment. Finally, the results of the program and recommendations for making improvements to the pilot program are presented.

Background

Union College is a small, private liberal arts college with about 2000 students, of which approximately 350 participate in engineering programs. It is predominately undergraduate and residential. Union operates on a three-term academic calendar. The fall term runs from early September until the Thanksgiving recess in late November. The winter term begins immediately after the new year and continues through the third week in March and the spring term commences in early April and extends through the first week or so in June. In contrast, METU is a very large, public technical university with major programs of research and graduate study. About 19000 students attend METU of which approximately 8300 participate in engineering programs. The mechanical engineering department at METU is, by itself, almost as large as Union College in terms of enrollment (about 1400 total students of which approximately 1000 are at the undergraduate level). METU operates on a traditional semester calendar with two fourteen-week semesters (exclusive of examination periods) comprising the academic year. The academic year routinely commences at the beginning of October and the fall term continues until the end of January. The spring term lasts from mid February through the end of June. The education system of METU is very much patterned after typical North American engineering schools and its instruction is entirely in English. The mechanical engineering program of METU has been evaluated as “substantially equivalent” to similarly titled accredited programs in the United States by ABET in 1996.

The notion of the international collaborative design experience between these two institutions developed as the result of three fortuitous and unrelated occurrences. In the first case, a visit to an alumnus of the electrical engineering program at Union College provided the initial exposure to engineering design done via computer networks over long distances. The alumnus, who operates a small, high-tech electronics company in the Washington, DC area, had recently hired two new engineers - one in Idaho and one in Singapore - neither of whom was planning to relocate to Washington, DC. Rather, each would maintain their current residence and function as a full member of the company’s design team using electronic communications. A brief demonstration of the equipment was sufficient to validate the concept.

Some months later, a Union College faculty member involved in the college’s East-Asian Studies Program conceived the notion of using the Internet to bring Union College students in contact with their student counterparts in Asian universities. This latter idea was more in the nature of a solution looking for a problem than a fully developed program. However, the application of the concept to the engineering senior design challenge emerged very quickly and the notion of the International Virtual Design Studio (IVDS) grew rapidly from that point.

A visit to the Middle East Technical University (METU) in Ankara, Turkey provided the last link in forging the pilot program. During discussions between the Dean of Engineering at Union College (Richard A. Kenyon) and the Associate Dean of Engineering at METU (Bulent E. Platin) - both mechanical engineers - it was suggested that METU and Union College initiate the IVDS program during the 1996-97 academic year to test the hypothesis that the IVDS program could indeed provide each group of students with both a meaningful design experience and the opportunity for a significant cultural interchange, all without leaving their respective home campuses. Following these discussions, during the Spring of 1996, mechanical engineering faculty from Union College and METU commenced discussions (via email) on the IVDS project format, administrative structure, and design studio hardware and software.

The Proposed Project

The pilot IVDS project was targeted at senior mechanical engineering students. Since seniors have the requisite engineering and project skills, both programs have senior capstone design experiences, and the faculty members involved in the project at both institutions are mechanical engineers. At Union College all senior mechanical engineering students take a two-term senior project course. This course is pursued either individually or as a team project. This capstone experience requires two oral reports and a final written report. Typically, the first term is devoted to planning and design while the second is utilized for construction and evaluation of the proposed design. At METU, the capstone design experience for all senior mechanical engineering students is ME 407 Mechanical Engineering Design. One component of this course consists of lectures in which topics related to design, economics, project management, human factors, and case studies are discussed. The other component of the course is a term project. ME 407 students form teams that range in size from two to four students and choose one of three projects
designed by the METU faculty as their term project. The students are then required to design their project and produce them in the department’s machine shop and test them at the end of the term in the ME 407 Design Competition. As part of the design process, each team is required to submit a design report, complete with engineering drawings, approximately mid-way through the semester. On the first day of the ME 407 Design Competition, students must present their designs to a jury made up of faculty and graduate assistants. The jury evaluates the designs on originality/creativity, engineering quality, robustness, aesthetics, and presentation. Students are penalized if their designs have major deviations from the submitted design report. During the second day of the competition the performance of the designs is evaluated in a competition format.

The logical fit for the IVDS pilot project was to have the Union College students participate in the fall term ME 407 course. This format accommodates the academic schedules and clearly fulfills the academic requirements of both institutions. Two IVDS teams were formed for the pilot program. Each of these teams consisted of two students from Union College and two students from METU. The Union College and METU faculty agreed in advance that the project for the IVDS teams would be the design of a vehicle without any wheel or wheel like contact with the floor. The vehicles were designed for speed, carrying capacity, efficiency, energy consumption, and aesthetics. They had to travel within a 30 cm wide path, carry a minimum payload of 500 grams, and were limited to a 12 volt power supply for energy. This project was chosen because the METU faculty had experience with a similar project in the past and all felt that for the pilot program it was best to use a project where the potential difficulties were mostly understood. This project was also offered as one of the three design project options for the other ME 407 students [6].

The IVDS designs were a collaborative venture between the Union College and METU teammates. Since both sets of teammates remained at their home institutions, the collaboration was accomplished through the use of telephone, Internet, and video conferencing technologies. Design studios at both institutions were set up to facilitate discussion and cooperation on this project. At the end of the project the Union College students traveled to METU to join their teammates for the design contest.

The Design Studio

Prior to the commencement of the IVDS project, design studios at Union College and METU were constructed. The design studios are a pair of remotely located rooms in which the two parts of the design teams came together, with access to all the necessary design tools and a communication system that essentially negated the distance that physically separated the two component parts of the teams.

The studios at Union College and METU were designed to enable students to: (a) communicate effectively and in a timely fashion with their international counterparts on a regular basis, (b) share various types of design files and documents (word-processing files, spreadsheets, data files, presentation graphics, and engineering designs), (c) interactively exchange ideas on a electronic whiteboard, (d) interactively share applications, and (e) share video images. This list of criteria is ordered, in what is currently believed to be, the most significant to the least significant insofar as achieving success of the project is measured.

The Union College design studio shown in Figure 1 is PC based and equipped for communication over standard phone lines (POTS) and the Internet. Distinguishing features of the studio include a Gateway 2000® Pentium®-200 MHz computer equipped with 32 megabytes of memory, 3 gigabyte hardisk, 21” Vivitron® monitor, SoundBlaster® 16 bit sound card, Altec® speakers, Creative Labs® PC-3000 DVC system, Coherent® Call Port, Cannon® VC-C1 MK II Video Camera, TelevEyes®/SC Computer-to-TV converter with audio, Zip® Drive, HP ScanJet® 4C, and HP DeskJet® 682C. The computer is connected to the Internet via a thick-wire Ethernet connection. Union College is currently subscribing to a T1 Internet service. Software available for video conferencing includes ShareVision® (POTS), NetMeeting® (Internet), and CU-SeeMe™ Enhanced (Internet). The studio was laid-out to accommodate up to four people video conferencing at the same time.

The METU design studio was also PC based and equipped for communication over the Internet. The distinguishing features of the studio include a 150 Mhz Pentium® computer with 32 megabytes of RAM, 2 gigabyte hardisk, 14” monitor, Creative Vibra® 16 sound card, Creative External TV Coder, 4x CD-ROM, 14400 fax/modem, HP LaserJet® 4MP, and HP ScanJet® 4p. This PC was set up as an NT-server that students could access through on campus computers or remotely from off campus locations. Originally there were plans to install a Creative Labs® PC-3000 DVC system in the computer; however, this system will not function below a 28800 bps baud rate and the Turkish telephone lines are at best 14400 bps unless a special leasing agreement is made for a dedicated line for higher baud rates with the local telephone company. The software available for video conferencing is NetMeeting® (Internet).

Both studios run in a Windows® environment and are equipped with the Microsoft Office Suite® and CADKey®. Students were encouraged to use these packages for their word-processing, spreadsheets, presentation
graphics, and CAD drawings. Any other software tools that the teams needed to complete their designs, such as simulation and mathematical packages, were left up to the students to identify and agree upon.

These design studios enabled students to collaborate over the Internet on their design projects. Initially the students used email, Internet “chat lines” and telephone communication. As the project developed NetMeeting was provided Internet voice communication and an electronic whiteboard. The electronic whiteboard proved to be absolutely essential for completing this project within the 16 week time frame of ME 407.

At the end of the project a beta version of NetMeeting proved to be unstable and now both sites are exploring the use of CU-SeeMe Enhanced and NetMeeting Version 2 for future conferencing efforts. CU-SeeMe Enhanced and NetMeeting Version 2 provide real-time video and voice, along with an electronic whiteboard, and limited application sharing. CU-SeeMe Enhanced also has a Reflector option that allows multiple parties to conference at the same time.

Discussion

In less than one year the International Virtual Design Studio (IVDS) project was conceived and the first set of students successfully participated in the project. This is not to say that there were not any difficulties, on the contrary; however, in the true spirit of international cooperation all parties worked diligently to make the first year of the project a complete success. Now it is time to reflect on this first experience in order to make improvements that will heighten the experience for future students participating in this project.

Figure 1: International Design Studio at Union College.

Internet communication technologies are critical to the success of the IVDS project. Initially in the pilot project only email, attachments, FTP, and chat lines were used to communicate between teammates. These asynchronous technologies did not supply the level of communication needed for preliminary and conceptual design discussions on a project in which a detailed design report had to be submitted within six weeks. To circumvent this problem, Internet discussions were supplemented with telephone conferences. This proved to be very expensive and did not provide an adequate level of communication for this design project. Telephone conversations do not allow concept sketches to be transmitted, details on drawings to be pointed to, or the interactive marking up of documents. About midway into the project NetMeeting was installed at both sites. NetMeeting allowed teammates to talk to each other over the Internet and use an electronic whiteboard to view and mark up sketches, drawings, and documents. The video camera in the Union College studio was also used to take and transmit still pictures that were then transmitted through the electronic whiteboard to the METU team members. At the end of the project a beta version of NetMeeting was installed in the Union College studio that would have allowed video transmission. Unfortunately, this version was not compatible with the available hardware and eliminated all conferencing capability. Since this time CU-SeeMe Enhanced and NetMeeting Version 2 are being evaluated for future IVDS projects.

The use of the various internet technologies varied throughout the project. During the preliminary design stage - which included conceptualization, development of design specifications, and development of design concepts - the Union College and METU students were in daily contact with each other. A majority of the design activity during this stage was performed over the internet. Emails with attachments and FTPs accounted for about 20% of this contact, video conferencing accounted for another 30%, and chat lines accounted for the remaining 50%. There was slightly less contact between group members during the detailed design stage. During this stage the students divided up the design responsibilities and contacted each other every two or three days to provide updates on their progress. About 80% of this contact was video conferencing and the remaining 20% was email and FTP’s. Contact between group members fell off to once a week during the construction and evaluation stage of the project. The majority of the students time during this stage was spent in the shop constructing the projects. The weekly contacts were to update the group members on construction progress and difficulties encountered. Video conferencing accounted for about 60% of the contact during this stage and the remainder was email and FTP.
Collaborating on a design over the Internet can be both a difficult and frustrating experience for students. A significant amount of time in this environment is spent mastering and maintaining the communication technologies. Collaboration over the Internet does force students to organize their projects. The seven hour difference between Schenectady, NY and Ankara, Turkey made it almost impossible for students to just jump on line and ask a question. Regular conference times were arranged in advance and students had to prepare for these conferences in order to make sure that all their issues were discussed. Although this type of collaboration is not ideal, it is the way engineers the world over are practicing their profession.

Collaboration over the Internet also makes it easy for students to become isolated from the rest of their team. It is very easy for one part of the team to just ignore their international teammates and pursue the project on their own. One way of preventing this from happening is to build into the structure of the program accountability of all students to both institutions. Accountability was informally built into the pilot program. Faculty from both institutions sat on the jury’s that evaluated the projects and a portion of the students grades were based on their level of participation in the project. Future IVDS projects will require students to build part of their project at one site and the remainder of the project at the other site. This format will force collaboration between international teammates. This format was not imposed during the pilot project because the Union College shop was not up to an appropriate metric standard. Efforts are currently underway to rectify this situation.

One aspect of teaming students over the Internet that cannot be overlooked is the teammates getting to know each other on a personal level. Allowing students to develop personal relationships with their teammates fosters cooperation and heightens the educational experience for the students. Students must be allowed and encouraged to engage in social discussions while on-line. Ideally the teams should be assigned before the start of the term to allow the students to get comfortable with each other and the technologies before they have to start working with each other.

The Union College students and faculty advisor traveled to Ankara, Turkey for the final design competition. This allowed the students to meet their teammates and enter their projects into the competition. A total of forty teams competed in the ME 407 Design competition. Sixteen of these teams (including both of the IVDS teams) submitted designs for a vehicle without any wheel or wheel like contact with the floor. The IVDS team entries into the competition are seen in Figure 2.

Figure 2: IVDS designs of a vehicle without any wheel or wheel like contact with the floor.

Plans for the next IVDS project are already underway for the Fall of 1997. The next IVDS project will incorporate an electrical component. This will mean that the IVDS teams will need to include both mechanical and electrical engineering members. It is anticipated that a mechanical and electrical engineer at each institution will be teamed with international counterparts. Future formats may see the mechanical engineering being performed at one institution and the electrical engineering being performed at the other. This project can also be opened up to other disciplines and to more than two institutions on a team. All of this is possible; however, it is very important to insure that the design challenge for each discipline is of an appropriate level. This requires cross disciplinary cooperation between faculty.

Future plans for the IVDS program also include the METU students visiting Union College just prior to the submission of the design report and Union College students visiting METU for the competition. This component of the project is being implemented to give both the Union College and METU students an opportunity to appreciate another culture and gain valuable international experience. The international experience gained on the IVDS project goes well beyond visiting another country and its culture. The IVDS project forces students to confront culture and language differences in order to achieve a common goal. This cannot be achieved on a traditional term abroad or exchange.

The IVDS project specifically addresses five of the eleven program outcomes included as “Criterion 3: Program Outcomes and Assessment” of the newly promulgated ABET Engineering Criteria 2000 [4]. These five program outcomes, as listed by ABET, are:
(c) an ability to design a system, component, or process to meet desired needs;
(d) an ability to function on multi-disciplinary teams;
(g) an ability to communicate effectively;
(h) the broad education necessary to understand the impact of engineering solution in a global/societal context;
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The IVDS concept also addresses albeit more generally, all but one of the remaining six desired program outcomes as listed by ABET.

Summary

The IVDS project piloted between Union College in Schenectady, NY and METU in Ankara, Turkey, during the fall of 1996, is an international collaborative design experience for seniors that incorporates components of the capstone senior design project and a term abroad. Using a combination of interactive video and Internet communications, two international teams of students undertook a single design and build project, sharing data bases and designs electronically, communicating both by e-mail and in real time through video conferencing, and building their respective portions of the final design at the individual institutions. The IVDS experience addresses 10 of the 11 ABET Engineering Criteria 2000 [4] program outcomes and assessments. The pilot project targeted mechanical engineering students. Future IVDS projects will include other disciplines and institutions around the world.

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