Establishing Effective, Multi-University Student Design Teams for Addressing Interdisciplinary Projects

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Abstract

Engineering endeavors have become increasingly more complicated and require engineers to interact effectively in teams with members of different cultural, social and technical backgrounds. Members of design teams quite often must interface electronically because of the great geographic distances between their locations. Therefore the telephone, fax, e-mail, computer conferencing and electronic means can become common communication tools between team members. Hence to fully use their technical talents, engineers must be able to work in interdisciplinary teams and effectively communicate across great geographical distances.

Collaborative design projects addressing environmental restoration and waste management needs of the Westinghouse Savannah River Company were addressed in our Capstone Design courses. The specific objectives of this effort were to identify and implement techniques which: (1) prepared the student to function in interdisciplinary design groups composed of members with diverse thinking styles (Teaming), and (2) enhanced effective communication using conventional methods and modern electronic technology (Communication). During the past four years a total of eight faculty members from four different universities and in four different academic disciplines have participated in this project. A total of 334 students have worked on teams that have addressed twenty-one different projects.

Introduction

Engineering endeavors have become increasingly more complicated and require engineers to interact in teams with members of different cultural, social, and technical backgrounds to accomplish the specified team task. This interaction can be difficult, but it is required if the engineer is to explore the potential solutions and fully understand the criteria and constraints of the project being addressed. Members of teams may be able to gather in a single conference room to discuss the problem but quite often they must interface electronically because of the great distances between their locations. Therefore the telephone, fax, e-mail, and other electronic means can become common communication links between team members. Hence to fully use their technical talents and to meet the challenges that they encounter in their careers, engineers must be able to work in teams and effectively communicate across humanistic, social and technical barriers.

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Universities have the task of educating student engineers who can provide effective and responsible solutions, both as an individual and as a member of a team, to human-social-environmental needs. For years capstone design courses have been used in single engineering disciplines and at single universities to foster the understanding of the design process and teamwork. However, much more is required to prepare engineering students to interact in teams with members of different backgrounds and to meet the challenges that they will encounter in their careers. Hence universities and industry need to work together to identify and eliminate those barriers to effective teaming and communication.

During the past several years, students and faculty of the University of South Carolina (USC), Georgia Tech, South Carolina State University (SCSU), and Clemson University have participated in collaborative design efforts addressing environmental restoration and waste management needs which are central and germane to the mission of the Westinghouse Savannah River Company. The project functioned for two years with only the South Carolina institutions participating, and they were joined by Georgia Tech during the last two years of the project. In addition to.addressing the needs of Westinghouse, the effort has had the objective of establishing effective procedures for addressing interdisciplinary design projects with multi-university student teams, and of preparing the students to function in interdisciplinary design groups composed of members with diverse thinking styles.

Objectives

The specific objectives of this project were to establish effective procedures for addressing interdisciplinary design problems with multi-university student teams. Even though this need has been discussed in various engineering educational groups, there have been no established efforts reported by other universities. Therefore this work may serve as a model and illustrates how interdisciplinary, multi-university teaming may be accomplished; it has already been the subject of two newspaper articles, two conference presentations, and articles in the university alumni journal and in an international professional journal.

The specific goals were to identify and implement techniques which: (1) prepared the student to function in interdisciplinary design groups composed of members with diverse thinking styles [Teaming], (2) enhanced effective communication using conventional methods and modern technology (FAX, e-mail, Phone Conferencing, Television Conferencing, etc.) [Communication], and (3) eliminated boundaries that prevented students from integrating course material and its application into real projects from engineering and engineering technology [Innovative Design]. These goals were addressed by involving seniors from four disciplines and four different state universities in real industrial problems. The objectives were identified as the most important elements that an emerging engineer needs to know in a study conducted by ASME and sponsored by NSF. Input to this study was sought from middle level industrial supervisors, professors and working engineers.

Methodology

The Westinghouse Savannah River Company, in coordination with the faculty involved, established broad “need statements” for several of their specific problems. The faculty then selected those problems which could be addressed most effectively by the interdisciplinary student teams in the available time. At the beginning of the semester the students from the universities were divided into multi-university, interdisciplinary teams. A typical student team was composed of a chemical engineering and a mechanical engineering student from Clemson, a chemical engineering and a mechanical engineering student from the

University of South Carolina, and a mechanical technology student from South Carolina State University. A faculty member from each affiliated university department was working on this project. Therefore a ChE and ME professor from Clemson, a ChE and ME professor from USC and a MET professor from SCSU were involved. These faculty and their students traveled to the Westinghouse site where the student teams were assembled and the problems were presented by Westinghouse personnel. During the remainder of the semester, each student team worked on the solution to their problem.

Faculty, representing the involved disciplines at each university, participated in this program to facilitate the work done by the students. Also faculty insured that the electronic communication systems were accessible for the students and served as technical consultants for the students.

Each student team selected a specific hour each week for a telephone conference, and scheduled one-half hour, biweekly, two-way internet computer conferences or television conferences over satellite channels operated by the South Carolina Educational Television (SCETV) system. In addition they transferred files, AutoCad drawings, etc. from one university to another using e-mail and fax. Each team practiced for their final oral presentation to Westinghouse personnel by using two-way computer or television conferencing.

At the end of the semester, the students traveled back to the Westinghouse SRS site where solutions for their problem were presented by each team in both written and oral format with appropriate proof-of-concept models. The solutions and reports were judged by Westinghouse personnel and by the faculty members. After the presentation of the final report, the students were asked to critique the techniques and communication procedures used in addressing their problem, to offer suggestions as to how their experience could have been improved, and to evaluate the contributions of each team member.

Each of three problems selected was addressed by one team composed of five students and one faculty member from each university in the Fall 1994. Hence fifteen students and three faculty were involved during the first semester of this project. The objective of the faculty in these initial problems, in addition to addressing the objective listed above and developing a solution for the problem, was to identify and eliminate any difficulties associated with the operating procedure and the communication links used by the students.

In late Fall 1994, all five faculty evaluated and made modifications to the project and selected three problems for the Spring 1995. During the Spring of 1995 there were twenty-two students involved, working on five teams of four or five members each. Two teams were assigned to each of two different problems and the fifth team continued on a problem that was begun during the Fall of 1994.

During the Summer 1995 the five faculty evaluated the work of the previous year and made plans to proceed into a second year of activities. During the Fall 1995 the program proceeded with 32 Clemson students, 34 USC students and 4 SCSU students or a total of 70 students working on three Westinghouse problems. Each of two problems were addressed by four multi-university, interdisciplinary teams of five students each, an interdisciplinary team of five students from a single school, and a five member team of single-discipline students from multiple universities. Hence six teams were addressing each of these two problems. Two other single-university, single-discipline teams each addressed a third problem.

In the Spring 1996 the five faculty directed the work of 37 students on three problems. The adjustment in the total number of students involved in the project was made to reduce the communication load of the Westinghouse liaison personnel. Two problems were new and were addressed by four teams each and the third problem was a continuation of a problem addressed in the Fall 1995. Also during the Spring 1996 two faculty from Georgia Tech (one in mechanical engineering and one in nuclear engineering) expressed an interest in working on the project with the faculty and students from the South Carolina universities. Hence, over the four years of operation of the project the eight faculty, from Clemson, SCSU, USC, and Georgia Tech worked with 334 students on 73 teams addressing 21 projects during the four academic years of the project operation. Some examples of the projects addressed by the student teams are:

Design of an 80 Watt Measurement Calorimeter,

Radioactive Sludge Transport System Design,

Repair Plug/Manipulator Tool Design,

Subsurface Impermeable Barrier Design,

Waste Vitrification Pour Spout Design.

Each of these problems included significant content for the contributions from the different student disciplines, and the students came to appreciate the value of the contributions from other team members.

In the early stages of involvement of students from a newly associated discipline, there seems to be a natural resistance to participation in interdisciplinary activities. As the semester continues, the students overcome this reluctance and then their solutions begin to take shape with genuine recognition of the true interdisciplinary nature of the problems.

Evaluation

Both the faculty and students, who have been involved with this project, support and value the results obtained. At the end of each semester the students were asked to write an individual report. A student from USC wrote, “Personally, I feel all USC Engineering students should be able to have an experience like this prior to graduating, however very few will have the same caliber of quality individuals supporting them as I have had the pleasure of working with the past few months.” This statement not only supported the concept of this project but also demonstrated the bonds that were built with student team members in other disciplines and at other universities. A Clemson student wrote, “Each member of the team brought unique skills, which seemed to complement each other.” The mechanical engineer technology students, the chemical engineering students, and the mechanical engineering students from the different universities each played roles in the solution of the problem. A student from SCSU wrote, “I feel that my contribution was significant and meaningful. My experience with the Westinghouse Senior Project has been extremely beneficial to me in gaining a complete education. I can clearly see the relevance of an innovative team of different engineering disciplines conglomerating {working} together on a project that has many different parameters.”

Also the faculty were asked to develop individual evaluations of the project, and each professor was responsible for assigning grades to his own students. Each design was evaluated by all of the faculty involved with that project as well as by the industrial liaison engineers. The mechanical engineering professor from USC who participated in this project stated “Overall I think that the program was extremely beneficial for the students. The projects showed the students that they can work with other disciplines. The students who participated now realize that they may not understand everything the Chemical Engineers are saying but there is common ground where they come to together. They also realized that it does take multi-discipline teams to get things done. This is not something that is stressed anywhere in the current curriculum at USC. Also the students had their confidence boosted by seeing students from other schools and seeing that they can hold their own.”

The mechanical engineering technology professor at SCSU said, ”Initially, there was some apprehension on how such a non-homogeneous group could work together. After the groups were formed, which consisted of students from the three university, and students sat down to work, it soon became clear that each group needed to tap the knowledge and skills from each member to find or propose a solution. Past MET graduates who went through the program now wish that each MET student could be exposed to the same experience. According to them, the knowledge and experience gained from working on these projects in multidisciplinary teams, greatly enriched their learning experience at South Carolina State University.”

In a letter to the principal investigator of this project, the manager of the process chemistry and control section at the Westinghouse Savannah River Company stated, “ During this time we have realized benefits from the student designs in several areas. Last semester their contributions to the Counter Current Decantation project for sludge processing and the designs for the remote placement of the canister weld plug were particularly helpful. ····· It appears that the senior projects program is very beneficial to the students. If you agree and would like to continue the program next fall, we would welcome the opportunity to work with you again.”

This project has been the subject of positive and complimentary articles in regional newspapers; the Anderson Independent (December 2, 1995), the Greenville News (December 31, 1995), and a feature article which appeared in the Spring 1996 issue of the Clemson World (the Clemson alumni journal). Also the Westinghouse Public Relations and Education Outreach office is developing a press release for the local media which explains the involvement of Westinghouse in this SCUREF project. In addition this project was selected as one of three design programs in the nation to be highlighted in the article, “Teaching Tomorrow’s Engineers” (Valenti, 1996).

Also one investigator presented a paper giving an overview of this project at a 1996 Symposium sponsored by the National Safety Council. Attendance at this symposium was by invitation only and was limited to department chairs in ME, CE, ChE, and EE, to industry managers (VP and middle level managers), and special guests. The invited papers defined topics for discussion in the workshops that followed the presentation of the papers. The anticipated outcome of this symposium included developing more effective techniques for teaching integrated design. The presentation was received enthusiastically by the symposium participants, and representatives of GM, John Deere, and Boeing inquired whether their companies could participate in the program.

Lessons Learned

This project was successful and has been the subject of much interest and discussion. Westinghouse, the students and the faculty all feel that they have benefited from the program. To insure the quality and consistency of the student's reports and work, a document was written and distributed to the students which defined what should be contained in the team's interim written reports, the individual final written reports, the team's final written reports, the log books, etc. Each student received a copy of this document, which helped insure that quality assurance goals were met, and that the students operated in a professional manner. Also the students were provided written information on teaming (How teams should work, problems typically encountered, etc.).

The Westinghouse personnel felt that during the Fall 1995 the limit had been exceeded as to the number of teams with which they could effectively interact. They felt that six teams were more than a Westinghouse liaison person could handle. Even though the number of viable solutions increased as the number of teams increased, it seemed to reach an effective limit at about four teams. Hence Westinghouse limited the number of teams per problem to four in the Spring 1996. This seemed to be an optimum number of teams.

Technology such as video conferencing, phone conferencing, and electronic mail can be difficult to use when crossing institutional boundaries. These difficulties are a result of differences in systems at the various institutions or some institutions not having compatible systems. Difficulties in the area of video conferencing led to purchases of computer hardware/software that allowed all the participating students to conference with each other on demand. Extensive use was made of computer conferencing after the spring of 1997 via ISDN lines as well other means of communication via the Internet. Each student team developed a Web site that served as a logbook for the team. The Web site had a public domain area and also a portion that was accessible via a password. All information specific to the project was kept in this password-protected area. Students made entries into the protected area of the Web site as they obtained information and developed their work. Thus this material was instantly available to other team members, both local and distant. The use of ISDN lines for computer conferencing and transfer of files and the use of Web sites as described above became the two major methods of communication.

It was observed that the multi-university teams tended to make uniform and consistent progress toward a solution whereas the single university teams did not progress as smoothly. Upon checking it was found that members of multi-university teams seldom allowed other activities to take priority over their conference meeting. When a TV conference or phone conference was scheduled, they were there with their assigned tasks completed. However single university teams did not always meet at their scheduled times and on occasion meetings were called off so that members could attend social activities. This is certainly a positive aspect of the multi-university format, but the conclusion of the investigators was that the additional costs, both in dollars and coordination time, made the use of interdisciplinary design teams at a single university more effective in the academic environment. The use of Web sites to maintain records and for instant communication between team members is very beneficial and is recommended for single university design teams. At Clemson, this semester, students in the disciplines of chemical engineering, ceramic engineering, industrial engineering, and mechanical engineering are working in twelve interdisciplinary design teams to address the problems of three different industrial clients.

Conclusions

The project met its objective of developing the students' skills in teaming, communication, and integrating the application of hard engineering science with safe, ethical and innovative design. The students, faculty, and the industrial client were all pleased with the results of the project and recommended that the program be continued. The project was made possible through funding from the South Carolina University Research and Educational Foundation, the Southeastern University and College Coalition for Engineering Education, and the Westinghouse Savannah River Company.

The faculty learned that the multi-university course required extra planning and significantly greater time spent in communication on a regular basis at all levels within the course format. Although the educational benefits of the multi-university format were evident, they were not sufficient to justify the additional expenses over the single university interdisciplinary course format. In either format it is very important to begin this type project with a small number of problems and gain control before allowing the scope of the course to expand and grow. Interaction between the student and the industrial client is necessary to reach the educational objectives and to develop a solution to the problem. One of the most significant lessons was to seek only those problems that were IMPORTANT to the industrial client.

References

Dixon, M. W. and C. H. Barron (1997) "Addressing Issues of Waste Management and Environmental Restoration with Interdisciplinary Design Teams," Proceedings of DOE Waste Management Conference, Tucson, AZ.

Dixon, M. W. and C. H. Barron (1997) "Establishing Effective Teaming and Communication Techniques in Multidisciplinary, Multi-University Student Teams," Proceedings of 1997 ASEE Conference, Milwaukee, WI.

Valenti, Michael (1996) "Teaching Tomorrow's Engineers," Mechanical Engineering, Vol.118/NO.7, ASME, New York, NY.

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