Cross-Disciplinary Teaming and Design

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Introduction

The ability to work effectively as a member of a team is one of the attributes that is consistently being identified in the many studies and calls for change in engineering education[1-6]. In most work settings, the engineer may be alone or in the minority of team membership. In the real world, the challenge of teaming must be met in a highly cross-disciplinary environment.

Problems that were discovered in introducing undergraduate engineering students to cross-disciplinary teaming with students in business and industrial design programs are reported in this paper. The use of product design as a focus of team activity was believed initially to be a good vehicle for preparing students from several different disciplines to perform on highly cross-disciplinary senior design project teams.

The results of the initial offering of an introductory course are summarized and their implications for undergraduate engineering education are presented.

Background

The Thomas Walter Center for Technology Management was established at Auburn University in 1989 for the purpose of improving engineering and business curricula. The intent is to prepare the graduates of engineering and business programs to exploit the competitive value of technology in the world of business.

A committee of engineering faculty identified the senior design project as a good first effort to bring faculty and students together from the colleges of engineering and business. Design of a new product for a local manufacturer was selected for the first project [7]. During the project it became apparent that the students had a wide variation of preparation for teaming and for product design. Subsequent projects reinforced this conclusion.

Because of the apparent value of focusing on the design of a product for a local manufacturer, the committee decided to invite faculty from the Department of Industrial Design to join the project and to help develop a course to introduce students to cross-disciplinary teaming and product design at the same time. Furthermore it was hypothesized that it may be better for the students to take this course during their sophomore year rather than immediately before the senior design project. This was based on the belief that the students would be more open to working across disciplinary boundaries as sophomores before their disciplinary specialization had begun.

A grant was received from the National Science Foundation to offer an introductory course to students from engineering, business and industrial design at the senior and sophomore levels to test the validity of the hypothesis[8]. In addition, by having subsequent senior design project teams made up of only students who had taken the introductory course and teams that had not, the value of the introductory course could also be assessed.

The introductory course was developed and offered by a team of seven faculty from electrical, industrial, and mechanical engineering, operations management, human resources management and industrial design. An eighth faculty member from the department of psychology was responsible for developing and implementing an assessment process.

This paper reports the results of the first offering of the introductory course to a group of seniors and the conclusions reached by one of the engineering faculty members that has been involved throughout the background described above.

First Offering of Introductory Course

The literature provides very little guidance on the preparation of students to work on cross-disciplinary product design teams that reaches beyond engineering. Teaming is a topic of current interest in engineering education and much is being reported on the formation, management and evaluation of teams of engineering students[9-18]. Some work is being done with teams that involve students from more than one engineering program[19]. The use of teams in capstone engineering courses was included in a survey of North American programs[20]. There has been some work with courses to expose business students to product design[21]. But this author is not aware of any other efforts to prepare undergraduate students from engineering, business and industrial design to work as a product design team.

Members of the faculty team relied on their collective experiences in teaching within their own discipline and their limited experience with a few cross-disciplinary senior design projects to develop the first version of the introductory course. Two team members have degrees in psychology and one of them has taught teaming to business students and conducted teaming workshops for industrial clients. The team of seven faculty members believed they had sufficient experience to design and conduct an introductory course on cross-disciplinary teaming and design.

The course was taught during a 10 week quarter with two major components. The first half was devoted to lectures and team exercises intended to introduce the students to the basics of teaming and product design. Team exercises during each class period provided an opportunity to put into practice the teaming and design concepts introduced in the classroom. The second half of the course was devoted to a mini-design project where each team was "pushed" through each of the product design steps culminating in a team presentation and report.

Each team was required to complete a conceptual re-design of an inexpensive hair dryer. Each team was provided one of the hair dryers as purchased from a local store. They were informed that the company had decided to redesign the product in an attempt to improve market share and overall profit. Instructions were provided on how they could place telephone calls, send and receive faxes, and obtain information for which there would be no cost to the students. Each team was given the same model hair dryer and instructions and informed that they would be in competition with the other design groups. They were instructed to prepare their final reports in a manner to convince their superiors that their design would be the best choice for the company and its objective to increase market share and increase overall profits.

Each team was required to make a presentation describing the design and submit a written report including drawings of the design. Each member of the faculty team reviewed these items and provided a grade for each team. These grades were compiled and a grade was determined for each team.

A grade was determined for each student by a mid-term examination grade and evaluation of class attendance and a personal notebook. At the conclusion of the course each student was required to provide an evaluation of the other members of his or her team. If two or more of members of a team gave another team member a negative rating, a weighting factor was calculated that reduced the grade received by the appropriate team member. The final grade for each student was a combination of his or her team grade, individual grade and team performance rating factor.

Students for the senior class were recruited through their respective departments. Faculty who were teaching junior level courses were asked to announce the availability of the experimental introductory course and interested students were asked to complete an application form during the pre-registration period. Special announcements were made to minority student organizations in an attempt to assure minority participation. The schedules of the students and the faculty were compared and a suitable time selected. All of the students who applied were notified of their formal acceptance. Not all students that initially applied chose to take the course. Initial enrollment was 30 and 27 students completed the course.

Assessment

One member of the faculty team was responsible for assessing the success of the project. For the introductory course this involved pre-course and post-course evaluations of the students as well as observations during the course of the class meetings and the team activities. The mid-term examination was designed to provide an assessment of the lectures and the team exercises used during the first half of the course. Each student was interviewed near the end of the course.

The data gathered by the formal assessment process is being used in conjunction with other data gathered during the full scale senior design project that followed the introductory course. These data are helping guide preparation for a second offering of the senior course as explained below.

Results

While the formal assessment process produced data covering a range of issues, the information presented here is based in part on incomplete assessment results. The observations and conclusions presented here are those of the author from the perspective of implications for engineering undergraduate education.

The students from industrial design were found to have highly developed product design skills in comparison to engineering and business students. Engineering students experienced difficulty in translating the general design problem into one or more "engineering problems" that they knew how to analyze. The business students had general ideas about dealing with market, manufacturing and pricing issues, but they were not equipped to quickly tackle the assigned problem. The engineering and business students defaulted to the knowledge and experience of the industrial design students. This resulted in the industrial design students dominating the projects and their feeling that they had to do more work than their other teammates. Although this problem was detected during the mini-project, little could be done to deal with each of the team situations because of the shortness of the project.

The faculty attempted to impress upon the students that the project was presented in a manner to simulate a "real world" design experience. In particular, incomplete information allowed the students to gather additional information about the manufacturer and the industry and to make assumptions as needed to complete the design on schedule. Students found this freedom difficult to accept. Most teams found it difficult to make specific assumptions at critical points in the design sequence and move ahead to completing a design.

Although the members of each team were required to take time in one team meeting each week to assess their performance as a team, these times became routine exercises that did not resolve problems within the teams and did not appear to produce significant learning.

Members of the faculty team were readily available each class period and usually more than one visited each team during a class team session. The faculty initially thought that the diversity of observations and suggestions from the different faculty would help develop the multi-disciplinary nature of each team's work. However, it gradually became apparent during the project that this strategy confused the students more that it helped. The students wanted the faculty to provide specific guidance on how to complete the project, whereas the faculty was encouraging the students to make decisions on their own. For example, the students were not given specific formats for their presentations or written reports. Rather, the faculty noted that they should recognize that they are attempting to "sell their design" and they should plan their presentation and report accordingly. The students found this freedom frustrating.

An attempt to offer the same course to a group of sophomores two quarters later was not successful. When it became apparent that the initial interest of the sophomores was not as great as the seniors, there was an additional effort to enroll sophomores. It was found that sophomore students were not sufficiently motivated, especially in engineering and business, to take the risk of volunteering for an experimental course. Moreover, the "sales pitch" that employers are looking for graduates with teaming skills carried little weight. Eventually, it was decided to not offer the course at the sophomore level, but to offer a refined version at the senior level. Some of the reasons for this decision are provided in this paper.

Conclusions

For truly cross-disciplinary teaming to be learned where engineering and non-engineering students participate, each student on a team must be equipped to contribute to the assigned problem using his or her own disciplinary knowledge and skills. The implications of this conclusion are two-fold. First, each student must be sufficiently along in his or her disciplinary studies to have specialized knowledge and skills that the other students on the team would not be expected to possess. Second, the assigned problem must present a challenge to each discipline represented on the team. While this conclusion may appear self-evident, in retrospect the faculty did not realize that the students had such dramatic differences in preparation for and experience in product design. The effect of these differences were exacerbated by presenting the design problem to the teams in a manner similar to that used in industrial design classes.

There should be specific requirements within a highly multi-disciplinary teaming course for each student to "back away" from the team experience and consider the problem and the team experience from his or her own "disciplinary perspective." For example, after the team work is completed each student could be required to report separate from the team on how he or she may have solved the problem without the benefit of the team experience. The student could be required to compare and contrast his or her individual conclusions and those of the team.

Formal sessions should be established by the faculty to periodically meet with each team and with each team member to engage in a reflection process for the purpose of helping each student be aware of the important principles that are being learned.

An introductory course to highly cross-disciplinary teaming will be most effective when the students have already developed basic teaming skills. Basic teaming skills can be learned in environments that are less complex and demanding than those where the specialized and differentiated knowledge and skills of several disciplines are involved. In the case of undergraduate students, the value of a highly cross-disciplinary experience is questionable before the student has developed some skills in applying his or her own discipline.

Overall it is concluded that product design is not a good activity to introduce highly cross-disciplinary groups of students to teaming. Basic teaming skills are best developed in environments that allow students to approach problems without any perceived major differences in their preparation.

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References

1. **Engineering Education for a Changing World**, A Joint Project Report, American Society for Engineering Education, 1994.

2. **Engineering Education: Designing an Adaptive System**, Board on Engineering Education, National Research Council, National Academy Press, 1995.

3. **Restructuring Engineering Education: A Focus on Change**, Report of an NSF Workshop on Engineering Education, National Science Foundation, April 1995.

4. Augustine, Norman R., "Socioengineering (And Augustine's Second Law Thereof)," **The Bridge**, National Academy of Engineering, Vol. 24, No. 3, pp. 3-14.

5. Vasilca, George, "Engineers for a New age: How Should We Train Them?" **The International Journal of Engineering Education**, Vol 10, No. 5, pp. 394-400.

6. Grayson, Lawrence P., "Educating Tomorrow's Engineers," **IEEE Education Society Newsletter**, Fall 1994, pp. 1-5.

7. Aldridge, et. al., published paper on first cross-disciplinary senior design project coordinated by center.

8. Introduction to Team-Based Design, NSF Grant # DUE-9354523, February 1, 1994-September 30, 1996.

9. Dally, J. W. and Zhang, G. M., "A Freshman Engineering Design Course," **Journal of Engineering Education**, Vol 82, No. 2, pp. 83-91.

10. Grubbs, Lbert B. Jr. and Zoghi, Ehbood, "Overview of a Capstone Project Prerequisite Course," **The International Journal of Engineering Education**, Vol. 9, No. 5, pp. 386-390.

11. Brickell, Col James L., Proter, Col David B., Reynolds, Col Michael F. and Cosgrove, Capt Richard D., "Assigning Students to Groups for Engineering Design Projects: A Comparison of Five Methods," **Journal of Engineering Education**, Vol. 83, No. 3, pp. 259-262.

12. Love, D. M. and Boughton, N. J., "Educating Tomorrow's Manufacturing Systems Engineers Today," **The International Journal of Engineering Education**, Vol. 10, No. 2, pp. 171-177.

13. Smith, Karl A., "Cooperative Learning: Effective Teamwork for Engineering Classrooms," IEEE Education Society Newsletter, April 1995, pp. 1-6.

14. Knox, Robert C., Sabatini, David A., Sack, Ronald L., Haskins, Robert D., Roach, Larry W., and Fairbairn, Scott W., "A Practitioner-Educator Partnership for Teaching Engineering Design," Journal of Engineering Education, Vol. 84, No. 1, pp. 5-11.

15. Rust, Jon P., Hamouda, Hechmi, Hewitt, Elizabeth R., Shelnutt, James W., and Johnson, Thomas, "Quality Improvement Partnerships with Industry Using Student Teams," **Journal of Engineering Education**, Vol. 84, No. 1, pp. 41-44.

16. Miller, Gregory R. and Cooper, Stephen C., "Something Old, Something New: Integrating Engineering Practice into the Teaching of Engineering Mechanics," **Journal of Engineering Education**, Vol. 84, No. 2, pp. 105-115.

17. Beaudoin, Diane and Ollis, David F., "A Product and Process Engineering Laboratory for Freshmen," **Journal of Engineering Education**, Vol. 84, No. 3, pp. 279-284.

18. Byrd, Joseph S. and Hudgins, Jerry L., "Teaming in the Design Laboratory," **Journal of Engineering Education**, Vol. 84, No. 4, pp. 335-341.

19. Johnson, Stanley H., Luyben, William L. and Talhelm, Donald L., "Undergraduate Interdisciplinary Controls Laboratory," **Journal of Engineering Education**, Vol. 84, No. 2, pp. 133-136.

20. Todd, Robert H., Magleby, Spencer P., Sorensen, Carl D., Swan, Bret R. and Anthony, David K., "A Survey of Capstone Engineering Courses in North America," **Journal of Engineering Education**, Vol. 84, No. 2, pp. 165-174.

21. Ulrich, Karl T. and Eppinger, Steven D., **Product Design and Development**, McGraw-Hill, 1995.

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