Interdisciplinary Team Projects With Marketing Students To Improve Engineering Capstone Experience

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Abstract

Marketing and bio-resource engineering faculty developed an interdisciplinary cross-course project for their senior students at the University of Maine. Marketing and bio-resource engineering senior level courses included the interdisciplinary project to provide students the experience of working on multidisciplinary teams. The project required the marketing and engineering students to work together on development of a product or service marketing plan directly related to an engineering capstone design project. During the first two years of implementation, the project has evolved towards a more cooperative learning format that has improved the development of the students' team building skills and their appreciation for a multidisciplinary perspective. Project evaluations show that the benefits of the multidisciplinary project have been apparent to most of the student participants.

Introduction

Engineering education is adapting to the new constraints of manufacturing and business needs. New ABET 2000 criteria are emphasizing new kinds of capabilities such as teamwork skills for engineering students. Under the new criteria, students must learn to work in multi-disciplinary teams, to stay abreast of current issues and to be aware of the impact on society and culture of engineered solutions. Although these ABET requirements will be met in various formats by different institutions, there is a consensus that these skills are necessary to create an engineering graduate prepared for today's workplace.

In response to the new emphasis on the teamwork approach that manufacturers are currently using and developing, faculty in marketing and bio-resource engineering at the University of Maine created an interdisciplinary cross-course project for their students. Two separate senior level courses included the interdisciplinary project to provide the students the experience of working on multidisciplinary teams.

With the joint project, engineering and marketing students work together on interdisciplinary teams to develop marketing plans for the design projects of the engineering students. The students gain the perspective of another discipline, work in a team atmosphere and experience the synergy that comes from bringing diverse viewpoints to a central theme. The marketing students experience, first hand, how designs evolve and change, and how they must deal with product development as they look at marketing possibilities. The engineering students learn to view their design project from the marketing perspective.

Background

Two major dynamics of business and manufacturing are concurrent engineering and customer-centered product development. Customer focus is perceived by some as the most important determinant of business success, and engineers must be prepared to function in the design process accordingly.[1] Concurrent engineering is a recent strategy for managing customer-centered design processes that has been acknowledged by many for its successes.

The basic principles of concurrent engineering are 1) integrated product development; 2) inclusion of all relevant perspectives on the product during design and development; 3) global integration of all stakeholder needs in the design process. These concepts combine rapid prototyping tools with constant inputs from all the people that will be involved with the product from its initial creation to the end of its life cycle. The inclusive nature of the process stresses meeting of customer expectations. The result can be a cost effective, robust design tolerant of manufacturing and use variations.[2]

A key to concurrent engineering success is a multidisciplinary design and production team that integrates business requirements, human variables and technical variables in the design process from the beginning. It requires emphasizing the design process in parallel with the product development. This parallel process means product designers must have effective communication skills, good team working skills and receptivity to the various pertinent perspectives as the design process is carried out. Members of the multidisciplinary design team also need to have a sense of responsibility for success of all components of the product. The team members should see the value of and be capable of creating a explicit documentation of the design, testing and product evaluation. Management must allow teams to be empowered and provide a reward structure that emphasizes success of the team over individual success.[3]

While team skills are critical to an engineer's effectiveness, another consideration for the engineering graduates of today must be preparation for numerous employer changes and flexibility to move within a company. Today's graduate is more likely to have several employers as well as several position changes. As a recent *Fortune*[4] article put it -- "In the new game people float from project to project, from team to team. Job definitions become blurred, titles become almost meaningless. What matters is what you know, how well you apply it to the business... and how much you get paid." Ability to market themselves and their skills will be a critical factor of the graduates' success.

For engineers not working primarily in manufacturing companies, there is an increased chance of being self-employed or working in a small consulting company because large companies are increasingly outsourcing or subcontracting specialized work. As subcontractors and consultants, the technical person needs to be able to market their services and expertise and that of their company, reinforcing the importance of the customer-centered focus in the arenas of construction and service engineering.

Engineering education should be preparing students to be customer-centered in their design process, able to work on teams and communicate their design work to all kinds of audiences. The new ABET 2000 requirements address these needs through program outcomes and assessment criteria. The requirements to communicate effectively, to work in multidisciplinary teams, to understand the impact of engineering solutions in a societal context and be aware of current events are all preparing students to practice engineering with their customers in mind.
Traditional engineering programs have not typically emphasized the development of the customer-centered perspective or multidisciplinary team skills. Assessment in education should provide a model of good manufacturing management that rewards team success and empowers teams to develop their own effectiveness, knowledge base and documentation of processes.

Curricular Changes In Other Engineering Programs

Increasingly, examples of curricular changes can be found in various engineering programs and colleges. Multidisciplinary teamwork and concurrent engineering in the classroom is most often used in capstone senior level courses that give students the opportunity to work through the design process. The Colorado School of Mines,[5] Auburn University,[6] Georgia Tech University,[7] and Arizona State University[8] are some of the places where concurrent engineering principles or multidisciplinary teams or both are a key component of the engineering capstone courses.

More recently, the multidisciplinary team experience is being brought into other courses besides the capstone to provide students with more opportunities to develop teamwork, design process and communication skills. For example, Arizona State University has developed the Manufacturing Enterprise Curriculum (MEC) in their Manufacturing Engineering Technology Program. MEC uses concurrent engineering principles in many of their mechanical engineering science courses. In the courses, the students use Total Quality Management and integrated product design with project management software.[9] At Western Washington University, the Engineering Technology Department has made alliances with the Colleges of Business and Economics and of Arts and Sciences for the development of multidisciplinary teams to work on design projects. They have integrated concurrent engineering principles throughout their curriculum.[10] The Departments of Chemical and Materials Engineering and Electrical Engineering at San Jose State University worked with science disciplines to develop an interdisciplinary course in semiconductor processing. The team approach for this course is set in a context of a start-up company culture and allows students to be actively engaged in the construction of their own knowledge base.[11]

Some courses create interdisciplinary teams of engineering and computer science students only. For example, small-group problem solving exercises are utilized for chemical engineering classes at the University of North Dakota. The exercises allow students to practice technical and communication skills simultaneously through group work.[12] At the United States Naval Academy, electrical engineering students use concurrent product engineering and graphics tools for an electrical circuit theory class. The course promotes the ability to read engineering drawings as a necessary communication skill for engineers. The format of the class emphasizes communication between engineers during the entire design process.[13]

Schools like Western Michigan University have responded to the new industrial paradigm by creating interdisciplinary educational programs for students of engineering. They developed the

Integrated Supply Management academic program that combines engineering and business training. The program was developed through partnerships with top-level industry executives.[14]

Educational programs that are implementing multi-disciplinary teamwork and concurrent engineering practices have been successful at integrating new educational requirements. They also often provide students with cooperative learning opportunities for gaining the basic technical knowledge and skills needed. An interdisciplinary semiconductor processing course at San Jose State University (SJSU) allowed students to experience a more cooperative learning environment that encouraged interdependence and lateral thinking and promoted oral communication. SJSU alumni rated the multidisciplinary design team experience as key in getting a suitable job. They listed 1) hands-on laboratory setting; 2) teamwork experiences and 3) technical content as the valuable aspects of the semiconductor processing course.[15] Interview surveys of recent electrical engineering hires corroborated the importance of an ability to communicate through a variety of mediums as a necessary component of undergraduate engineering training.[16] In line with the many positive responses to teamwork opportunities in the classroom, the joint marketing/engineering senior level project developed at the University of Maine was designed to offer engineering and marketing students the interdisciplinary perspective, teamwork skills and communication skills they need to be successful.

Project Description

The Two Courses

1. Engineering Course

The Bio-Resource Capstone Design course supplies engineering students and their products or services to be marketed by the interdisciplinary team project. This course is a two semester course. In the first semester, students learn about the fundamental precepts of the design process, choose a project, conduct a literature and patent search to determine solution options and choose a particular solution that they then design. In the second semester, the design is built or implemented, tested and evaluated for its efficacy. This course provides the senior student an applications-oriented design experience. Students are expected to utilize concepts and skills attained in their engineering science and design courses during the design process and in the presentation of their solution. During the process, the students will demonstrate their ability to understand and apply scientific principles and engineering knowledge. Each student works with a faculty advisor and in many cases, industrial partners. As many student projects as possible are chosen from industrial connections that give the student the constraints of time deadlines, environmental and regulatory laws and budgetary limitations. Theory and methods of design solution development are discussed in lecture sessions. Students develop a design solution, document their solution, build a prototype or testing model and test and evaluate their design. The design process and the resulting solution are presented both orally and in a written report to the bio-resource engineering faculty who evaluate the quality of the outcome. The student is evaluated upon the complexity and quality of the final solution as well as their ability to communicate the design.[17]

2. Marketing Course

The Marketing Research course encompasses the study of analytic procedures (e.g. quantitative and qualitative research methods) needed by marketing management to reduce decision-making uncertainties. The course is designed to emphasize a hands-on approach to marketing research. The course includes problem formulation, exploratory research, research design, basic observational and sampling requirements, data analysis, interpretation and sampling. The course objective is to learn about marketing research at a variety of levels, from mastery of basic concepts and terminology, to application of marketing research techniques through projects and computer assignments. Emphasis is placed on written and oral communication and the development of skills involved in formal and informal participation. Introductory courses in marketing and basic statistics are required of the student enrolling in marketing research. Students at the senior level generally take the course.[18]

Development of the Collaboration

The marketing-engineering faculty collaboration came from conversations with an engineering project manager[19] from John Deere Company. The manager related an experience of a new engine design team at John Deere utilizing design engineers, marketing managers, sales managers and manufacturing staff. Faculty from bio-resource engineering and marketing decided they wanted to create a similar team experience for students. At the time the project was initiated, it was not framed from an understanding of concurrent engineering, but since that time the instructors have realized that the goals of the multidisciplinary project fit closely with many of the principles of concurrent engineering.

Objectives Of The Collaborative Project

In the first two years of the course collaboration, the learning objectives for all the students involved were:
1) develop teamwork skills,
2) deal with and understand people from different backgrounds and experiences,
3) develop "ownership" of the design by marketers and of the marketing of the product by engineers, and
4) deal with the ambiguity inherent in developing and marketing a new product or service including the need to devise a systematic approach to the process.[20]

Methodology

Table 1 shows the number of students by discipline participating in the first two years of the collaborative project.[21] At the end of the engineering/marketing collaboration each year, students were given an evaluation form designed to assess their perceptions and the effectiveness of the experience. Engineering student evaluation forms had slightly different wording than the marketing student forms to accurately address the differing concerns of the two perspectives. Average responses of selected questions from the evaluation form are given in Table 2.[22]

Table 1. Number of students participating in courses with joint project.[23]

Discipline	Year One	Year Two	Total
Marketing	23	30	53
Engineering	4	8	12
Total	27	38	65

Interdisciplinary teams were established by instructors with one engineering student or design team assigned to a group of four or five marketing students. An interdisciplinary team used the design project of the engineering student as the product or service for the marketing feasibility study. The engineering students provided technical information to the marketers, and the marketing students provided the engineer with ideas to improve the marketability of their design and with marketing strategies for the finished product. The information provided to the engineers included definition of the target market and initial specifications of the marketing mix.[24]

Team building activities were dealt with differently in the first year than in the second year. There were no joint class meetings for the marketing and engineering students during the first year. The marketing students received various handouts about working in groups, team building and documenting meetings. These subjects were covered in a lecture format by the marketing professor. The marketing professor also met with the engineering students, provided a lecture on basic marketing concepts and informed them of their team assignments. Meanwhile, the engineering students in the first year took part in team-building exercises as part of their senior seminar class. Engineering and marketing students were expected to set their own team meetings outside of class.[25]

In the second year, four scheduled joint sessions of engineering and marketing students were held. These sessions were planned to facilitate team interaction and conduct team building activities. Activities in these sessions consisted of handouts and assignments covering team building, group dynamics, developing a plan of action and recordkeeping for meetings. The joint class meetings were held in an interactive workshop format where student teams could consult with both engineering and marketing professors. Students also were encouraged to have team meetings outside of class as appropriate to develop the marketing plan. In both years, engineering and marketing faculty informally interacted with the students involved to see how the engineering-marketing teams were progressing and to see if there were any major issues that needed to be addressed.[26]

The marketing students were required to keep a meeting journal to record their team's progress toward completing the project. There were three purposes to the journal: 1) to encourage more frequent group meetings, 2) to provide a focus for each meeting and 3) to create a shared terminology dictionary of words frequently used in each discipline but not shared across disciplines. Additionally, the marketing students created a written report and oral presentation

Table 2. Average ratings for selected evaluation items and overall value of project by marketing and engineering students.[27] (Evaluation Form Scale: 1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree)

Topic	*Engineering*		*Marketing*	
	Year 1	Year 2	Year 1	Year 2
1. My marketing/engineering group made a sincere effort to understand my engineering/marketing perspective.	3.75	4.43	3.09	3.70
2. My marketing/engineering group was courteous and respectful.	3.50	4.57	4.22	4.23
3. My marketing/engineering group was patient in answering questions.	3.25	4.29	3.04	3.30
4. My marketing/engineering group was open and constructive in their communication with me.	3.00	4.29	3.48	3.67
5. My marketing/engineering group explained their part of the project thoroughly.	3.00	4.00	3.30	4.00
6. My marketing/engineering group was patient in answering my questions.	3.75	4.00	3.96	4.20
7. I have learned a great deal about marketing new products/services from this project.	2.75	3.00	3.96	4.27
8. I have a better sense of the issues involved in starting a business or marketing a new product.	3.00	3.00	4.00	4.17
9. I really had to be creative in searching for information about my product or market.	3.50	3.14	4.09	4.13
10. My communication skills or skills in working with groups have improved from this project.	2.75	3.29	4.13	3.97
11. From working on this project, I have a better idea what the “real world” implications would be for some of the engineering decisions or recommendations that I would make.	3.00	2.83	4.26	4.18
12. Overall, I think this was a valuable project.	4.00	4.00	4.17	4.18

of their feasibility study that was the culmination of the joint project.[28]

Discussion

Joint team building exercises conducted in class in the second year with students in their project teams produced much better results than the first year when team building exercises were taught separately by the two disciplines. The difference in team dynamics was most apparent in the final oral presentations for the team projects. In the first year, no engineering students participated in the presentations while in the second year the majority of the engineering students participated in the final presentation of the marketing plan.

In the second year as well, problems in group dynamics were addressed earlier by the students. The solutions to these problems were more functional and did not lead to isolation of group members. Evaluation results confirmed that the second year methods were more successful for enhancing the cooperative experience than first year methods (see Table 2). The engineering students in the second year found the marketing students to be much more open and constructive in their communications than was found in the first year. The explanations about their part of the project were perceived to be much better for both discipline groups the second year than the first year.

Through the collaborative process the students changed substantially in their acceptance of others' inputs into their projects. Most valued the opportunity to interact with someone outside their own discipline. They seemed to learn a great deal not only about the perspective of another discipline, but about the limitations of their own perspective. Average results of question 1 of the evaluation (see Table 2) shows engineering students rated their marketing team members higher with regard to their appreciation of another perspective than marketing students rated the engineering students. Questions 7, 8 and 11 indicated that the engineers did not seem to gain as much new knowledge about marketing concepts as the marketing students gained about product development and marketing.

The contrasts highlighted through ongoing communication with someone who did not speak their professional "language" seems in many cases to have helped students clarify their own assumptions, terminology, and theoretical perspectives. They also realized how these could be broadened by appeal to another perspective. Working with others from a different discipline was at times frustrating and annoying for some students. One of the ongoing tasks for the collaboration is to find ways to alleviate the frustration. Students need to appreciate the talents and contributions of each other earlier in the process, rather than at the end or sometime later in their careers.

Initially in the project, some engineering students were hesitant to allow others to observe and comment on their designs. However, after they had participated in the teamwork, there were some marked changes made to their designs. Describing their design concepts to their marketing group was helpful to the engineers in the development of their ideas and solution process. Sometimes the insight was just a better understanding of their own ideas, but many of them had not previously thought of their design in terms of its acceptability in the marketplace. For some the teamwork experience changed the whole emphasis for their design project, while for some they realized errors in their project plan or design.

By far the most successful aspect of the project for the engineering students was an improved understanding of their designs resulting from communicating their design process and ideas to non-engineering students. The engineering students were put in a situation that compelled them to communicate their design to someone with a non-technical and customer-oriented perspective. This caused the engineering students to articulate their own process in a new way while still in the midst of the process. As they discussed their design with their team, they would have to justify their process differently – in a way that could be useful for marketing. As they explained their process and reasoning to the marketing students, they developed a clearer appreciation of the adequacy or inadequacy of their design to address their initial problem.

Sense of ownership of the students for the marketing feasibility study was higher for the marketing students than the engineering students. The engineering students, particularly in the first year, did not feel a part of the process of developing the marketing feasibility plan. Evaluation results indicated that the marketing students felt the need to be (and therefore probably were) more creative in the project than the engineering students. The marketing students felt that they had gained a better understanding of real world issues than the engineering students (see Table 2). These results suggest that the engineers were not as appreciative of the marketing role as the marketers were of the engineering role, but more data needs to be collected particularly for engineering students before we can say this conclusively.

In the second year, there was definite improvement in this area for the engineering students; however, it still was not to the level that instructors would like. The sense of ownership was greatly enhanced by inclusion of class time for interdisciplinary meetings in the second year, but this is still a problematic area. There is a disparity in the percent of the course grade that the joint project constitutes between the engineering and marketing courses. The marketing students have been graded on their participation and outcomes, with a significant proportion of their semester grade attributable to their performance on this project. This was not the case for the engineering students' final grade in the first two years. It was originally thought that the fact that the engineers were designing the project would be enough of an incentive for them to welcome marketing input to their design. In reality, some engineering students viewed the marketing work as more of a drain on their time rather than contributing benefit to their project.

The engineering instructors saw a great benefit from the interdisciplinary assignments that the engineering students often did not perceive. The engineering instructors concluded that their students did not develop ownership of the marketing plans because rarely did the final written and oral reports of the engineering design include marketing information. In order to encourage greater ownership by the engineering students, a portion of the engineering capstone grade will depend on participation of the engineering student in the marketing plan development and acknowledgement of the marketing study results in the student's final presentation.

The instructors wanted to encourage the student teams to develop their own product or service to market, their own methods and their own structure for their feasibility plan. It was important to allow the experience to be student-centered and utilize cooperative learning, so the students could actively develop their own style and methodologies to permit creativity within the guidelines of the assignment. Students were given basic guidelines about the minimal requirements for the project. However, in order to conduct a truly complete feasibility study, students had to figure out what information was relevant, research it, and devise the best way to present their ideas. For example, one requirement was to describe the target market. It was up to students to decide the best classification scheme for describing those customers.

The most discomfiting aspect of this project for the students always seemed to be the openness of the project outcomes. The student teams had to define the scope of the feasibility study themselves and determine what marketing information would be most helpful to the engineers. Both the marketing students and the engineers experienced stress over their attempts to define the scope of the project. However, the ambiguity of the process models reality much better than a highly structured assignment would. In the future, one area to improve will be the support offered to students working through this definition process, both in terms of defining the *process* more and in terms of providing *feedback* on their plans and outlines once they are formulated.

The effectiveness of the team journaling requirement was dependent primarily on the marketing students because they had the most at stake in terms of a grade. The engineering students contributed little to the team journaling effort, because they did not have a part of their grade at stake. For the marketing students, it was found that the journaling supported the students' ability to analyze the progress of the marketing study. Through linear regression[29] it was determined that grades on the journals were significantly related ($F=9.51$, $p<0.01$, $R^2 = 0.20$) to final written report grades with a positive relationship. However, the journal grades were not significantly related to the final oral presentation grade ($F=0.11, p<0.74$). These results indicate that journaling was helpful in developing a written report but did not contribute to the success of the oral report.[30]

Future Initiatives

A new enhanced approach to multidisciplinary marketing/business/engineering education is being considered now by the bio-resource engineering faculty and the College of Engineering at the University of Maine due in part to the success of the efforts and results of the joint project described herein. The new approach will no longer be limited by the constraints of the scheduling of two separate courses. Instead, an independent interdisciplinary course that students may choose in lieu of the traditional engineering capstone or marketing research experience is being developed. The regular engineering capstone and marketing research courses will not continue with the joint project activities once the new interdisciplinary course is offered. The new course will teach concurrent engineering principles more explicitly than the previous collaboration did. It will also include rapid prototyping tools and other means of documenting and developing the team work process while the product development process is also being carried out. The techniques of team journals and in-class workshops for developing team skills will also be included to emphasize a cooperative learning approach for the new course.

Summary

During the first two years of implementation, the project has evolved away from instructor-centered tools such as crossover lectures and defined requirements toward more student-centered tools like joint workshops and planning tools with more cooperative learning activities. The marketing students rated the overall value of the project slightly higher than did the engineering students, but averages on the evaluation forms for both groups showed that the students had a positive and valuable experience. The benefits to students make it apparent that the collaborative project of creating interdisciplinary teams is a valuable experience for them although course work methodology is still developing. Many of the difficulties experienced within the engineering-marketing student teams were worked out, and it is anticipated that a new course structure will further improve the multidisciplinary experience for students. The initial collaboration has been an important beginning at the University of Maine to providing students with the new tools that industry and the business world are requiring of graduates today.

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