Case-Study Based Course - A Tool for Teaching Engineering Principles in a Non-Engineering Program

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Abstract

In the early 1990's, James Madison University developed a unique baccalaureate degree program. Called *Integrated Science and Technology*, the program was in response to industry need for university graduates with a broad knowledge of science and technology in conjunction with excellent computer, analytical and problem solving skills. These are well-trained undergraduates with the unique ability to manage a broad range of technologies and solve science, technology, and engineering related problems and the wherewithal to make an immediate contribution to industry. Accomplishing this goal from a teaching viewpoint required a paradigm shift in the way science and engineering courses are traditionally taught in universities. It required the design of courses with sufficient breadth, depth, technical rigor, and relevance to industry and real life. Five years ago, the authors developed a course solely based on real-life engineering problems designed to accomplish these seemingly mutually exclusive goals. In this paper, we discuss our experiences, students' reactions to the course, and some of the issues and dangers associated with this approach in a non-engineering program.

1. Introduction

In response to a call for reform in the teaching of science and technology, James Madison University started a unique baccalaureate degree program in the fall of 1993. [1,2,3] Aptly named *Integrated Science and Technology* (ISAT), the program is an integration of the study of science, mathematics, technology, engineering principles, information and knowledge management. The goal of the program is to produce graduates with excellent problem-solving and communication skills, and the technical wherewithal to effectively deal with the potpourri of interdisciplinary and constantly changing science, technology, and management related problems in industry. Their knowledge of science, engineering, and business management will be sufficiently broad and deep as to enable them play a central role in solving scientific and technological problems in a wide range of industries. They will have an appreciation of economic, social, political, and legal constraints that affect decision-making in industry and real life. Thus, an ISAT graduate is expected to have the following characteristics[4]: (i) technological problem-solving skills; (ii) breadth of knowledge and skills across a variety of scientific and technological disciplines; (iii) excellent problem-solving, collaborative and leadership skills; (iv) ability to use the computer as a problem-solving tool; and (v) the ability to integrate scientific and technological factors with political, social, economic and ethical considerations in problem-solving techniques.

Through the sophomore year, the ISAT program requires students to take classes that emphasize the role of science and technology in society, discrete and continuous mathematics, information systems, knowledge-based systems, statistics, organizational behavior, chemistry, physics, biology, environmental science, engineering, manufacturing and instrumentation and measurement.[4,5] These courses are designed to provide the student with the fundamental knowledge of science and engineering principles and introductory knowledge to transition into the technology sectors in the junior and senior years. In the junior and senior years, students pursue deeper study in six strategic sectors, namely biotechnology, energy, environment, engineering and manufacturing, information and knowledge management, health systems, instrumentation and measurement, and telecommunications. Also, at the senior year a student acquires deeper understanding by selecting an emphasis or concentration area. This requires a student to take a minimum of four 4xx-level courses and six credit hours of capstone work (i.e., 18 credit hours) in a specific technology area. To broaden their undergraduate education, students, in addition to the ISAT courses, must also satisfy a required 30 credit hours of liberal studies (general education) electives. Twenty-one credit hours are available as approved electives to encourage the student to develop further in an ISAT related area of interest. The capstone of the program is a senior project, in which students work in teams of four to six members to solve an industry or government-related problem. These problems are usually interdisciplinary in nature and usually require the student to use knowledge acquired from different disciplines within the ISAT program.

The ISAT program is driven by two major objectives. The first objective is to produce undergraduates with a solid foundation in science and its methods, and understanding of multi-faceted, interdisciplinary, practical approaches to solving technologically based business, industry, and government related problems. These are university-trained undergraduates who can make immediate technical contribution to industry (or government). Accomplishing this effectively requires a paradigm shift in the educational philosophy and methodology used in teaching science, technology and engineering. It calls for a pedagogy that emphasizes student learning. The second objective of the ISAT program is to attract and retain historically underrepresented groups in science and technology such as females and minorities. This calls for an inherently nurturing program that combines scientific theory with hands-on experiences designed to motivate and stimulate interest as well as impart learning. In this paper, we describe a course we developed five years ago that has attempted to effectively meet some of the goals of the program.

2. Rationale

A common theme in the call for reform in the teaching of science and technology is the emphasis on the process of student learning. That is, to adopt teaching methods which actively engage the student and facilitate student learning. These methods are sometimes preferred to the traditional lecture-based teaching method where students are viewed as passive learners. Some of the teaching methods suggested include one or a combination of the following: active learning, cooperative learning, collaborative learning, learning teams, and experiential learning. By definition, active learning involves the engagement of students in activities that require the application and use of concepts that are taught in the course to solve relevant and preferably real life and practical problems. In the context of this course, however, active learning consisted of students acquiring, analyzing or interpreting information and making proposing potential solutions to a variety of industry related problems.

At the onset, ISAT faculty recognized the need for a pedagogy that incorporates different elements of the above-proposed student-centered learning methods. However, successful execution of an adopted pedagogy is obviously predicated on the following: the subject matter, desired depth and breadth to which topics are to be covered, the classroom environment and type and background of students taking the course. There are several challenges in teaching an engineering course in a non-engineering program like the ISAT program and liberal arts institution like James Madison University. One of the challenges involves the selection of topics or concepts to teach and determination of the breadth and depth. Because the course is being taught to students who are not naturally inclined to enroll in an engineering program, the class environment and the teaching method are more critical than it ordinarily would be in a traditional program.

3. The Case Study-Based Course

Driven by the desire to develop an engineering related course that will meet the ISAT objectives and keep pace with the constant rapidly changing technologies, a course (ISAT 433) entitled Selected Problems in Manufacturing was developed and was first offered in the Fall of 1997. The three credit hour course is case study based and addresses selected problems encountered in the manufacturing industry. Over the course of a semester, students are given a total of three written engineering cases selected from the manufacturing industry dealing with one or more of the major manufacturing areas, such as engineering materials, processes, and systems. The cases involve materials and process selection, process and product improvement, materials handling, and product failure analysis. They include real-life problems from industry and those based on issues of interest to the manufacturing and materials industry. Examples of cases used successfully in the course include: selection of engineering materials for the manufacture of automobiles and beverage containers; workflow continuous improvement project, plant layout, operational efficiency studies, and work methods studies.

The course consists of a one-hour class meeting for weekly update and progress reports and at the end of five weeks, a two-hour class meeting for 20-30 minute presentation of final results and recommended solutions by each team. Students are given about five weeks to solve a given case, present results and make recommendations. During the first week of the course and at the beginning of each case study, the students are divided into teams of 3 or 4 students. After formation of the teams, each team is assigned a whole case or an aspect of a large case. The faculty and/or company representative usually presents the background of a given case. Completion of case studies usually involves research, literature survey and the collation, analysis, and interpretation of technical and historical data. Each team is required to present its findings in a 20-30 minute oral presentation to the class, faculty members, and industry representatives and to write a final report with recommended solutions to the problems. Depending on the nature of the case, the final report may be required to be at least 15 pages long with more than 20 references of published papers, preferably from refereed journals.

There have been some variations of the above sequence of events over the years, ranging from multiple projects per group to a semester long project - when project complexity and difficulty warranted it. In later years we tested students on general understanding and knowledge of important issues around projects they did not directly work on as an added incentive for them to pay attention when other projects were discussed in class. The class format also required students to participate in class discussions and suggest solutions to any manufacturing problems any student team is trying to solve.

4. Course Evaluations

The course was evaluated every semester during the last week of classes. It has continued to receive very favorable overall rating over the five-year period it has been taught. Following are some representative favorable and unfavorable comments from students about the course. For privacy considerations, we have not included student comments that were directed at individual professors.

Question: What do you like about the instructor or the course?
Student Responses:

- "It is real life so I think it will help us a lot in the future. Good course.
- Ideas were discussed freely among students and teachers. It was a very interactive class. I liked that there were no tests/quizzes. We were able to apply what we learned in previous classes to this class.
- Each instructor had a different perspective on each topic. This was beneficial as many different solutions were offered. Overall, the course was very unique.
- I liked the course required us to go out and take initiative for research. I liked the close atmosphere between students and teachers.
- Professor allows students to think and make decisions on their own, while providing necessary support
- I think this is one of the better courses I have taken in the ISAT program. It gave me much more hands-on learning experience.

- It did teach me a lot; however, it was also extremely overwhelming and stressful at times.
- The ability to learn topics assigned without being lectured to.
- Interesting way it is taught, all through the projects. Encourages teamwork environment, good presentation for real world activities".

Question: How can the course, teaching, or laboratory component be improved?
Students Responses:

- "I understand the importance of learning how to work with others and be able to solve problems without direction; however, I think it is unfair for an entire grade to be based on a group project.
- It was very difficult working with an outside company.
- Our project was not well defined and even the professors had little understanding of what the scope was.
- Not structured from the beginning, no gauge of grade distribution until the last quarter of the class.
- Final paper should not be 80% of my grade.
- The course could have better defined expectations and grading policies. There need to be conformity amongst the professors.
- My main objection to this course came in the performance evaluation. I believe that it is impossible to judge each individual on the whole group. With only three projects, the other group members' performance can determine your grade. The projects given had varying scopes and therefore cannot be compared".

5. Benefits and Challenges

As the student responses clearly show, students benefited from the exposure to the knowledge and perspective of more than one instructor. They also agreed that it brought some real life experiences to the classroom and allowed them to apply and integrate some principles they learned from earlier courses - thereby complementing the capstone (senior project) program requirement. Some of them appreciated the complexity and variety of projects the entire class was exposed to and learned from. A greater number of students appreciated the course format and content after they started working in industry - we receive very favorable calls and mails from some of our graduates, usually admitting that they now see the benefits of a course that is based on real life manufacturing cases.

However, some students struggled with the course format - what they called *"lack of structure"* and grading. They expect and have been used to very detailed multi-level syllabi that told them what to read every day, the exact page numbers to read, and how the course grade is distributed between homework assignments, tests, quizzes, etc. Some of the students would then pick and choose what to concentrate on and expect instructors to constantly remind them of the details in the syllabi. These types of students (our experience is that they were in the minority, but a very vocal minority) were not pleased with the independence and responsibility this course offered them. Another common concern that students expressed was the perception, and sometimes reality, that some of them worked harder than other team members for the same project grade. They felt that the allocation to other components of the grade (tests, class participation, etc.) was minimal and did not sufficiently compensate individual effort. There was also the complaint that some projects were more challenging than others - our assurances that they would see similar situations in real life was not comforting to these students, but we attempted to take this into consideration in assigning project grades.

The benefits of the case study based course were not limited to the students it also applied to the instructors. The instructors benefited from the team teaching environment, resulting in some cases, the development of new teaching methods and approaches. Involvement in the course also exposed the instructors to a variety of approaches and solutions to different manufacturing problems and manufacturing professionals, and companies with potential for consulting work.

Team members have been challenged by the amount of time required to coordinate a course like this. Instructors put in a lot of time to develop relationships with manufacturing firms that open their employees and operations to students. Selection of project ideas, working out the logistics for data collection, and supervision of about ten different projects require a lot of investment in time - it is a three-hour course and there is no load adjustment available. Adjusting to common grading standard and making necessary compromises on individual teaching styles have resulted in minor conflicts that students have noticed in some cases. One of the major challenges has been the lack of consensus on how to deal with difficult students - this has been more of an issue when there are more than two team members.

6. Conclusions

We feel that the course has been a success. In the five years that the course has been offered, we have successfully exposed our students to valuable organizational and group dynamics, complex and real life projects, and a potpourri of manufacturing problems that they are unlikely to encounter in a traditional college course. We have continued to modify and improve the course to address some of the legitimate concerns of the students, instructors, and our industry project sponsors.

7. References

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