

EVALUATION OF AN ENGINEERING EDUCATION COURSEWARE ACROSS DIFFERENT CAMPUSES¹

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Abstract - In order to meet some of the objectives of ABET 2000 criteria and to bring real-world issues to engineering classrooms, many different engineering education materials were developed by two of the authors. The materials consist of written case studies, videos, and CD-ROMs. They were used in engineering classrooms at different universities. In this paper, we discuss the evaluation of the courseware entitled "Della Power Plant" in engineering classrooms. In this courseware, the engineering and management issues surrounding the heavy vibration of a turbine-generator unit in a power plant are discussed. The Della CD-ROM won the 1998 Premier Award for Excellence in Engineering Education Courseware.

Subsequently, this courseware has been administered in engineering and business classrooms at Auburn University and at a minority engineering program at Alabama A&M University. Two of the authors evaluated the effectiveness of the courseware in these classrooms as a means of integrating engineering theory and practice. They found that the case study method of teaching received favorable responses from the students. The comments from the students were sprinkled with phrases such as "real life," "real situation," and "real world."

We believe that widespread use of courseware similar to the one discussed in this paper could develop the skills and techniques necessary for engineering practice and bring theory and practice together. It could also help realize many of the ABET 2000 criteria.

Index Terms - Engineering practice, Evaluation, Multimedia case study, Real-world issues

INTRODUCTION

Establishing Goals and Educational Objectives

ABET (Accreditation Board for Engineering and Technology) expects engineering programs to develop the

ability of the students to apply pertinent knowledge to the practice of engineering in an effective and professional manner. They state that engineering programs must demonstrate that their graduates have:

- (a) an ability to apply knowledge of mathematics, science, and engineering;
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data;
- (c) an ability to design a system, component, or process to meet desired needs;
- (d) an ability to function on multi-disciplinary teams;
- (e) an ability to identify, formulate, and solve engineering problems;
- (f) an understanding of professional and ethical responsibility;
- (g) an ability to communicate effectively;
- (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;
- (i) a recognition of the need for, and an ability to engage in, life-long learning;
- (j) a knowledge of contemporary issues;
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

They expect that each program should have an assessment process with documented results. The assessment process should demonstrate that the outcomes important to the mission of the institution and the objectives of the program are being measured.

For example, Prados, Editor of the *ASEE Journal of Engineering Education*, says, "Today, the environment for engineering practice is changing dramatically and irreversibly, impelled by the shift from defense to commercial competition as a major driver for engineering employment, the impact of exploding information technology, corporate downsizing, and the outsourcing of engineering services, and the globalization of manufacturing and service delivery. Employers increasingly emphasize that success as an engineer requires, in addition to strong

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technical capabilities, skills in communication and persuasion, ability to lead and work effectively as a member of a team, and understanding of the non-technical forces that profoundly affect engineering decisions. Acquiring such characteristics in a four, five, or even six-year program is unlikely with traditional, lecture-based instruction." [1].

Case studies have been identified as an appropriate method in order to achieve the goals [2]. In the Laboratory for Innovative Technology and Engineering Education (LITEE) at Auburn University, we have been developing and testing case studies in cooperation with industries to improve teaching engineering students. The goals and educational objectives of the instructional methodology adapted by LITEE are shown in Table 1. We describe in this paper the methodology of creating a case study, its administration in classrooms at different campuses, and evaluation results.

METHODOLOGY

Case Study

We worked with a major power company and have created the Della Power Plant case study. The objective of the Della case study was to show that good decisions require that managers become involved in understanding unfamiliar technologies and strike a balance between technical, financial, and management issues. A problem presented in this case study was the heavy vibration when the 120,000 pound turbine-generator unit at Della Power Plant was taken up to a high speed during start-up. The manufacturer's representative diagnosed the problem as due to possible breakage of some parts and recommended that, at a cost of \$0.9 million, the unit be disassembled and retainer rings be inspected. The plant engineer diagnosed that the problem was due to an oil whip and recommended that the turbine-generator unit be restarted immediately. The cost would be nil if the unit functioned properly and could be as high as \$19.5 million if the unit failed during a restart. The plant manager had to make a difficult choice between restarting the turbine-generator unit or shutting it down for maintenance considering the financial, technical, and safety issues.

An instructor's manual was developed to help other instructors use the case study effectively. The instructor's manual has the following sections:

(a) Brief synopsis of the case: An overview is provided, and the most important points about the case study are identified.

(b) Teaching plan: The expected flow of discussion in the class, assignment into groups, role-plays, and uses of videos are discussed here.

(c) Research basis: A disclosure of the basis of the research and the theoretical underpinnings of the research are provided here. References are provided so that the instructors could perform further analysis of the case study.

(d) Assignment questions: A full analysis of each question is made. We highlighted analytic points that might be noticed only by the best students - points that differentiate the top students from others.

(e) Epilogue: Follow-up information about the decision actually taken is provided in this section. The case study along with the instructor's manual was published in the Case Research Journal [3].

Assignment to Students

The students were divided into four groups. Two groups assumed the respective roles of the manufacturer's representative and plant engineer and debated their recommendations. A jury group assumed the role of the plant manager and decided the final choice that needed to be implemented. A future-technologies group proposed new technologies. The case study was administered in classrooms at Auburn University and Alabama A&M independently. Questionnaires were administered at the end of the case study discussion and were analyzed using quantitative and qualitative procedures.

Administration Of Case Study In Two Different Engineering Classrooms

Although the case-study method of instruction has been used on other occasions in both engineering and business classes at Auburn University [4], the use of this particular case study was introduced for the first time to a class at a different university. If students at Alabama A & M respond to the Della Steam Plant case study as favorably as their student counterparts at Auburn University, then the effectiveness of this particular case study can be accepted more readily, and it can be concluded that instructor effect or environmental context did not play an important role in the students' reactions. In this section the responses of students at Alabama A & M to the Della Steam Plant Case Study are compared and contrasted with the responses of students at Auburn University.

Concepts of Engineering Design (ME 260) is an engineering course at Auburn University in which theories of design are taught to engineering majors who are typically in their sophomore or junior years of study. Usually, this course is the first engineering course students encounter in their programs of study. In order to make the course more relevant and practical to students, case study method of instruction was introduced in this course. With the Della Steam Plant case study, students learned concepts of design while problem-solving real world dilemmas that have been encountered in industry. As part of a full evaluation of the effectiveness of the case-study method of instruction, students ($N = 23$) in ME 260 (Concepts of Engineering Design) were given two separate evaluation forms at the completion of the case study during fall term, 1998.

In addition, students ($N = 17$) in a class at Alabama A & M university were given two separate evaluation forms at the completion of the Della Steam Plant case study spring term, 1999. This particular sample of students was predominantly seniors (76%) with strong grade point averages (a range from 2.85 to 4.00, with over half above a 3.00) majoring in electrical engineering (94%). They have had little real-life work experience, with only 56% having had a job and 37% having worked in an internship. In other words, the case-study method of instruction could be of particular benefit to this group, as this method simulates real-life experiences.

Evaluation Results: Questionnaire I

Questionnaire I consisted of 24 bipolar descriptors. In other words, an item on the evaluation form would represent the concept of clarity on a 5-point continuum from unclear to clear or the case study's relevance on a continuum from irrelevant to relevant. The respondents would circle a number on the scale from 1 to 5 which most closely corresponded to their attitude toward that element of the case study. The respondents continued to follow this process through all 24 bipolar descriptors. Because the 24 questions yielded substantial reliabilities for four clear concepts or constructs, the analysis for Questionnaire I was organized by the following four case-study descriptors: (a) interesting and exciting, (b) important and valuable, (c) instructionally helpful, and (d) relevant and useful.

For the various items which related to the case study's sense of interest and excitement, the alpha reliability coefficients were .66 and .80 for the respective classes. The items used to rate the case study's importance and value yielded an alpha of .80 and .86 respectively. The items used to rate the case study's ability to be instructionally helpful yielded an alpha of .75 and .90 respectively; and, finally, the items used to rate the case study's relevance and usefulness yielded an alpha of .65 and .90 respectively. Again, because these four constructs derived from Questionnaire I yielded substantial reliability levels (with anything above .60 considered acceptable), the 24 separate items within the survey could be meaningfully organized and reported by these four distinct descriptors of the case study.

Because Questionnaire I did not use specific qualifying statements but, instead, asked respondents to identify their attitude on a 5-point continuum, it is difficult to provide detailed information for this evaluation. However, because a score of 5 would represent the most positive reaction to the descriptor, it can be assumed that any score above a 3 indicates a favorable response to that particular construct for the case study. Table 2 shows the medians for responses on the four separate constructs.

Indeed, the medians for all four constructs for the Auburn University class were well above a rating of 3, indicating that students rated the case study on the positive side of the continuum. In fact, as demonstrated by the

construct with a median of 4.0, the students found the case study particularly relevant and useful—important elements in effective learning. For Alabama A&M students, the median ratings, all of which are equal to or exceed 4.0 for the each construct, indicated that the students there found the Della Steam Plant case study to be an effective educational tool. As demonstrated by the final construct with a median of 4.5, the students found the case study particularly relevant and useful.

Evaluation Results: Questionnaire II

Questionnaire II asked the respondents to indicate the extent of their agreement with 16 evaluatory statements on a 5-point Likert scale. Some sample items include statements such as "I improved my ability to evaluate critically technical and managerial alternatives" or "I learned to design." The response scale progressed from a rating of 1 which represented the least positive or least favorable response of strongly disagree to a rating of 5 which represented the most positive or favorable response of strongly agree. In addition, in Questionnaire II a qualitative element was added to the evaluation process. The form ended with three open-ended questions which asked the students to provide written responses concerning the strengths and weaknesses of the Della Steam Plant Case Study as well as suggestions for improvement.

As with Questionnaire I, substantial reliabilities for Questionnaire II suggested specific constructs, which made an analysis of the data manageable and meaningful. The constructs which occurred were the following: (a) perceived skill development (alpha = .88 and .95), (b) self-reported learning (alpha = .71 and .90), (c) intrinsic learning and motivation (alpha = .69 and .79), (e) communication skills (alpha = .61 and .39), and (f) ability to learn from fellow students (alpha = .63 and .54). Please note that the reliabilities generally were above the established criteria of .60. The medians for these five constructs derived from Questionnaire II are reported in Table 3.

With the exception of communication skills, Table 3 illustrates that the reactions of the Auburn University students to these various aspects of the Della Steam Plant Case Study were favorable. Self-reported learning, intrinsic learning and motivation, and ability to learn from fellow students (all yielding medians of 4.0) were highly rated by the students. In other words, the Della Steam Plant Case Study appeared to be well received and educationally advantageous to the students. The median rating of 2.5 for communication skills is not problematic. Because the instruction associated with the case study did not directly address communication skills, it seems logical that students might not report a change or improvement on this particular construct.

The reactions of the Alabama A&M students to these various aspects of the Della Steam Plant Case Study were favorable. Interestingly, although the reliability was

questionable, the responses to the items for the construct of learn from fellow students produced the highest rating of 4.5. Perceived skill development, self-reported learning, and intrinsic learning and motivation, important instructional outcomes of the case study method, all yielded medians of 3.7 or above. In other words, these constructs were highly rated by the students. In general, the Della Steam Plant Case Study appeared to be well received and educationally advantageous to the students at Alabama A & M.

Qualitative Comments

The qualitative section of Questionnaire II provided additional favorable responses to the Della Steam Plant Case Study. All 23 respondents at Auburn University chose to elaborate on the strengths of the case study project. Of the total responses, 13 of the students (57%) commented on the benefits of incorporating real-life applications of problems into an engineering design class. For instance, one student commented the following: "It showed me a real world situation and was exciting to see if we made the same decision as the real engineers." Another student noted that the "overall case study was helpful in bringing real-world issues to the classroom." And yet another student stated that the case study was "a good concept and a valuable tool for exposing students to real life engineering issues."

The second prominent theme that occurred in response to the case study's strengths was its assistance in developing cognitive skills such as decision-making. Ten of the 23 respondents (43%) commented on the development of decision-making skills and practices. For example, one student noted that he "was allowed to think, analyze, and make decisions on [his] own and within the group." Similarly, another student stated that he could "analyze and defend different aspects of the problem." This same student later noted that the strength was the "integration of technical and non-technical forces of decision making." The third prominent theme which occurred in the response to the case study's strengths was the students' enjoyment of the opportunity to work collaboratively with their peers in teams, which one student described as "so crucial to engineering and industry." Six of the students (26%) commented on the benefit of the group work, specifically "strengthening communication and interactiveness of members." All other comments made by students described the Della Steam Plant Case study as "interesting," "straightforward," and "well-defined."

Concerning the weaknesses of the Della Steam Plant Case study, all but one of the students opted to respond to the question. Eleven of the respondents (48%) would like to see more technical information added which would help in gaining a better understanding of the design problem. For instance, one student noted that the "technical aspects that should be present in most case study reviews was not present in this one." Another student stated that "there were important details left out of the CD and out of the printed

material." The second theme which occurred concerning a weakness of the Della Steam Plant Case Study, a lack of necessary time, was commented upon by eight (35%) of the respondents. For instance, respondents noted that "time constraints were too tight" and "There was not enough time available to be very thorough. The case was too rushed for the expectations that were set out." The final comments made by three students asked for clearer directions, expectations, and guidance concerning the assignments related to the case study itself.

The final question in the qualitative section of the evaluation asked the students for suggestions in improving the case study. Five of the 23 respondents chose not to respond or offered no suggestions for improvement. The other primary themes which occurred all related to the weaknesses which had been mentioned in the earlier paragraph. Eight of the respondents requested "more technical data," "more information," or "more details." Six of the respondents wanted additional time, and five of the respondents wanted the expectations of the assignments to be clarified. For instance, one student stated the following: "Let the students know more about what to do and give more time." Another student stated, "Make it clear to the students what is expected. . . . Give us more time to coordinate groups and get our stuff together." One student gave the following helpful suggestion:

Perhaps have an example case study presented prior to the presentations, not on Della, but another case study. This will help in determining what's expected. Also, an outline or perhaps more communication in regards to the write-up following the case study is needed.

In general, the comments from the students were positive, favorable, and supportive of the case-study method and the Della Steam Plant Case Study in particular. The suggestions the students made were thoughtful and beneficial in terms of providing formative evaluation information, which will help in finding the most effective methods for implementing the use of case studies to teach the concepts of engineering design.

The qualitative section of Questionnaire II provided additional favorable responses to the Della Steam Plant Case Study from Alabama A&M students. Twelve of the 17 respondents (71%) chose to elaborate on the strengths of the case study project. Of these 12 responses, five of the students (42%) commented on the benefits of incorporating real-life applications of problems into the theoretical learning that occurs in class. For instance, one student commented the following: "It helped me to identify with real world problems and situations." Another student noted that the case study "gave me a chance to put myself in a live situation." Consistently, from other surveys given on other case studies, this connection of theory and real-world practice tends to be the major theme emphasized by students as a strength of the case study-method of instruction. The second prominent theme that occurred in response to the

Della Steam Plant Case Study's strength was its professional presentation, replete with information. Thirty-three percent of the students mentioned the abundant and organized information available through the case study. One student made the following comment: "The Della Steam Plant Case Study was very organized and put together well." Two students each also mentioned the case study's proficient incorporation of technology and their increased understanding of different individual's opinions as a result of group work. One student mentioned his improved ability to evaluate situations due to his involvement in the case study.

Concerning the weaknesses of the Della Steam Plant Case Study, only nine of the 17 respondents (53%) decided to elaborate. These nine comments did not fit any one particular pattern or theme. Two students mentioned that they did not have adequate time to complete the case study. Otherwise, only one student each commented on the following perceived weaknesses: lack of information, lack of group participation, lack of shared decision making, an unfamiliarity with turbine engines, and an unfamiliarity with other plant procedures.

The final question in the qualitative section of the evaluation asked the students for suggestions about how to improve the case study. Only eight (less than half the class) decided to offer any suggestions, and, like the weaknesses, these suggestions covered a range of topics instead of falling into a clear theme or pattern. Two students suggested actually visiting the plant site. One student each offered the following advice: find a new computer system to integrate all information, provide more information, discuss plant policies and procedures, increase general discussion, make problems more life-like, and provide more explanations. The fact that no consistent pattern emerged for either case study weaknesses or improvements suggests that no distinctive or apparent faults exist within the Della Steam Plant Case Study. Rather, students made individual suggestions based on their personal needs and interests.

CONCLUSIONS

Both the quantitative data and qualitative data suggest that the students benefited from the use of the Della Steam Plant Case Study as an instructional tool. Specifically, the students found the case study to be valuable, useful, realistic, and relevant. The students reported growth in learning and skill development as a result of their involvement in this case study. The students seemed to enjoy this particular medium of instruction. The responses of both sets of students—those from Alabama A & M and those from Auburn University—indicated that the Della Steam Plant Case Study enhances learning. The students enjoyed the activity, and the students

felt that they benefited from the activity. Regardless of the environment, context, or instructor, the Della Steam Plant Case Study was rated favorably by students as a valuable educational tool.

The Della Steam Plant case was a great success for the Auburn University and Alabama A&M students and faculty involved. Our experiences with the case were motivating and encouraging and motivated us to share this case study with several other groups (South East Advanced Technological Education Consortium, Sigma XI participants, ASEE participants, high school teachers, and maintenance engineers). Most of them were impressed that this experience presented a real problem faced by engineers. Today's students are intimately familiar with web browsers and cases work well when delivered in this manner. We never had to help the students navigate the case or find the appropriate information. We only needed to show them where the case study was located. It is also beneficial to include audio, video, and links to enhance the presentation. Making the case studies multi-media makes it easy to update and deliver to students at locations off campus [5].

We learned that students could tackle more significant and challenging problems through the case method. We also saw this as an effective tool to enhance their critical thinking and problem solving skills.

We believe that widespread use of case study in other engineering classrooms similar to the one discussed in this paper could develop the skills and techniques necessary for engineering practice and bring theory and practice together. It could also help realize many of the ABET 2000 criteria.

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Table 1: Educational Objectives to Achieve Research Goals

Goal	Educational Objectives
<i>Bring theory and practice together</i>	<i>The students need to:</i> - understand non-technical forces that profoundly affect engineering decisions - understand technical forces that profoundly affect engineering decisions. - understand importance of team work and communication in engineering practice
<i>Develop higher- level cognitive skills</i>	<i>The students need to:</i> - identify criteria to solve problems in unstructured situations - analyze alternatives given multiple criteria - make a choice and defend the choice persuasively - be actively involved in learning situations

Table 2

Medians for Constructs in Questionnaire I with Different University Students

University	Interesting and exciting	Important and valuable	Instructionally helpful	Relevant and useful
Auburn	3.3	3.5	3.8	4.0
Alabama A&M	4.0	4.2	4.3	4.5

Table 3

Medians for Constructs in Questionnaire II with Different University Students

University	Perceived skill development	Self-reported learning	Intrinsic learning and motivation	Communication skills	Learned from fellow students
Auburn	3.8	4.0	4.0	2.5	4.0
Alabama A&M	3.8	4.0	3.7	3.5	4.5