Teaching Real-World Issues through Case Studies*

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ABSTRACT

Engineering students are expected to be not only technically proficient, but, also to exhibit a sound awareness of real-world issues such as marketing, finance, communications, and interpersonal relations. We found that this is best learned by participating in a case study method of instruction. This paper describes the results of a research undertaken by the authors to develop a teaching methodology to bring real-world issues into engineering classrooms. It describes the steps taken in developing an engineering-management case study, administering this case study in a classroom, and results of evaluating the effectiveness of this method of instruction. In particular, it focuses on the students' and professional engineers' perceptions on the utility of the case study method of instruction in engineering classes. The results of the research lead to recommendations to funding agencies and educators on the need to develop interdisciplinary technical case studies so that the innovations happening in the engineering world can be communicated to the students in the classrooms.

I. INTRODUCTION

The teaching of domain-specific knowledge has long been recognized to be the primary objective of undergraduate engineering education. But many graduates are found lacking the breadth of knowledge and skills that are fundamental to the practice of their profession. According to L.G. McCraw, the CEO of Flour Daniel in reference 3,

Many engineering graduates know little about finance, marketing, communications, customer supplier relations, law, or any of the other professions that make up the internal workings of a company. In the competitive global marketplace, this kind of knowledge is not just an added value, it's a necessity.

Therefore, there is a growing need to put a greater emphasis on imparting cross-disciplinary education (such as finance, marketing, communications, etc.), in engineering classrooms. This can be learned best by solving complex, multifaceted real-world problems. Real-world problems allow the students to vicariously experience situations in the classroom that they may face in the future and thus help bridge the gap between theory and practice. The need of university education to expose students to real-world issues is best explained in this quotation by Whitehead in reference 6:

The careful shielding of a university from the activities of the world around us is the best way to chill interest and to defeat progress. Celibacy does not suit a university. It must mate itself with action.

Lectures or "teaching by telling" is the traditional and the most widely-used mode of instruction in engineering colleges. The most frequently cited drawback of the lecture method is that it usually results in long periods of uninterrupted instructor-centered, expository discourse, relegating students to the role of passive spectators in the classroom. This method, however, continues to be the most dominant teaching method in the engineering colleges and is used in most classes. For example, most mechanical engineering design courses make the students work on oversimplified theoretical representation of real-world problems. This experience makes the students obtain an in-depth understanding of the design principles. But, they are not trained to link the theories to solving practical problems that occur in real-life. Therefore, we investigated the use of the case study method of teaching in order to communicate real-world industrial experience in engineering classrooms. The success of the case method in business schools has inspired educators to recommend its adoption in engineering education. Although case studies were used in engineering curriculum during the 1970s, there are only a few of them available currently that could be readily used by faculty members in a classroom. In addition, very few faculty members in the college of engineering know how to administer the case studies in their classrooms. Therefore, we believe that there is a strong need to develop case studies that describe technical issues along with financial, marketing, and management issues. The authors had an opportunity to develop a technical case study to illustrate a maintenance problem that occurred in a steam power plant. A written case study was developed based on this scenario and run in four sections of an advanced design project course at Auburn University. This paper describes the development of this case study, administration of the case study in the classrooms, evaluation by the students of this experience, and feedback from industry managers. The results of this project led us to make recommendations for funding agencies and educators on the importance of developing case studies in engineering education.

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II. WHAT IS A CASE STUDY?

A case study typically is a record of a technical and business issue that actually has been faced by managers, together with surrounding facts, opinions, and prejudices upon which management decisions have to depend. These real and particularized cases are presented to students for considered analyses, open discussion, and final discussion as to the type of action that should be taken. The fundamental principles underlying the case study method of teaching as summarized by Barnes et al., 10 are:

1. The primacy of situational analysis: Analysis of some specific situation forces the student to deal with “as is” and not the “might be.”

2. The imperative of relating analysis and action: The traditional academic focus has been to know; the practitioners’ focus has been on action. The case study method of instruction seeks to combine these two activities.

3. The necessity of student involvement: The active intellectual and emotional involvement of the student is a hallmark of case study method. That involvement offers the most dramatic visible contrast with a stereotypical lecture class.

4. A nontraditional instructor role: The instructor’s role is not so much to teach students as to encourage learning. His/her role is more of a facilitator and he/she has to be both a teacher and a practitioner.

5. The development of an administrative point of view: The students develop an understanding of the problem from a holistic point of view and not from an engineer’s perspective alone.

III. DEVELOPMENT OF THE CASE STUDY

The authors developed a case study based on an actual problem that happened at a steam power plant and which involved decisions that cost millions of dollars and endanger human safety. The authors visited the power plant in order to learn the problem first-hand. They met with Steve Potts, the engineer in charge of preventive maintenance. He was visibly excited that he had helped solve an important maintenance problem in one of the turbine-generator units. The authors recorded the conversation with the engineer on a micro-cassette and later had it transcribed into textual material. This material formed the basis of the first iteration of the written case study. One of the authors is a professor in mechanical engineering and interpreted the technical information. The other author is a professor in management and interpreted the financial and risk information. The engineer and manager from the power plant attended the classes where the case studies were discussed. These visits provided the authors further information about the problem and the issues involved.

The authors sent this material to the engineers and the managers at the power plant and requested them to make changes to the case study in order to improve its authenticity and accuracy. The plant personnel also supplied the necessary charts, photographs, and other evidence that needed to be included in the case study. A short summary of the case study follows:

This case study involved three principal characters working at Della Power Plant-Sun Towers, the plant manager, Lucy Stone, the RLS engineer, and Steve Potts, the engineer in charge of predictive maintenance. The Della Power Plant produced and sold electricity generated by turbine-generator units. A 120,000-pound unit was taken up to a high speed in order to check the balance. But the unit started to vibrate and then rolled to a stop. Many employees were scared and started moving away from the unit. Everyone around the turbine thought that it was going to come apart. Lucy diagnosed the problem as due to an imbalance and possible breakage of some parts. She recommended that the unit be disassembled and retainer rings be inspected, even if it took a week to do so. The cost of such a decision would be approximately $0.9 million. Steve studied the charts that were generated by the proximity sensors he had attached to the turbine-generator unit. He diagnosed that the problem was due to oil whip and there were no major imbalance problems. He recommended that the turbine-generator unit be restarted immediately. Although this decision would be beneficial in providing immediate revenue, if the unit failed during a restart, the company would have to replace the unit leading to a cost of $19.5 million. Sam, the plant manager, was in a dilemma since this was the first time that his engineer and RLS engineer had disagreed on a major maintenance problem at the power plant. He 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.

The authors rewrote the case study incorporating the changes suggested by the plant personnel and presented it at the 1995 North American Case Research Conference held in Orlando, FL. 11 The case study was mailed to a panel of experienced case writers before the conference. During the conference, the authors met with the panel in a round-table discussion. The panel was very appreciative of the effort by the authors in bringing engineering-management issues to the forefront. They felt such case studies were essential for communicating real-world problems to engineering students. They also provided an effective critique of the case study. Their critique was on improving the writing style, sharpening the decision focus, and providing an accurate explanation of the financial and technical data. They wanted the dilemma faced by the manager of the power plant, Sam Towers, to be highlighted. Based on this feedback, the authors rewrote the case study and an instructor’s manual. The dilemma was restated as: that a good decision requires that the plant manager become involved in understanding unfamiliar technologies, a situation that many managers experience. This formed the final version of the case study that was administered in the classrooms. 12

IV. CASE OBJECTIVES

The objective of the Della case study is to show that good decisions require that managers become involved in understanding unfamiliar technologies and strike a balance between technical, financial, and management issues. Engineering students have to interpret the charts based on knowledge gained in earlier courses on the principles of vibration, alignment, balancing, and maintenance of turbine-generator

*For those who are interested, the detailed case study, an instructor’s manual, and a multimedia package for this case study may be obtained from the authors for a nominal fee.
units. They also have to analyze the financial, management, and credibility issues and use this information in making a good decision. It shows that a good decision evolves when engineers learn to appreciate management and financial issues and managers become involved in understanding unfamiliar technologies.

V.ADMINISTRATION OF THE CASE STUDY

The case study was administered over a two-year period. It was used to teach 74 senior level undergraduate students in four sections of a mechanical engineering advanced design project course. The students were provided the case study and, a week later, were given two hours to discuss their findings to the class. The students were divided into four groups. Two groups assumed the roles of Lucy and Steve and debated their recommendations. A jury group assumed the role of Sam Towers and decided the final choice that needed to be implemented at the power plant. A future technologies group proposed new technologies. The task expected of each group is shown below:

Group 1: Assume the role of Lucy and defend recommendation 1—Stop the turbine-generating unit and fix problems. Include technical, financial, safety, and credibility issues.

Group 2: Assume the role of Steve and defend recommendation 2—Restart the unit the same day. Include technical, financial, safety, and credibility issues.

Group 3: Assume the role of Sam Towers, the plant manager, and decide between the two recommendations. Defend your answer and state how you used the information provided by the earlier groups.

Group 4: Assume the role of a new technology group and discuss technologies that could be used in the future to solve such problems. Include measurement, data collection, information presentation, and communication issues.

The four groups prepared for the discussion by concentrating on the roles assigned to them. They went to the library, consulted other professors, collected corroborative evidence from textbooks and journal articles, and prepared the presentation material. During the day of the presentation, the problem was introduced to them by the power plant engineer who visited the classroom. He demonstrated the intensity of the vibration problem by bringing a rotor-kit up to a 16 mil level of vibration. Thereafter, each group discussed the problem using their assigned roles. A summary of the typical responses provided by the student groups is provided below:

Group 1: Assume the role of Lucy and defend the recommendation to stop the turbine-generating unit and fix problems.

1. The chart (figure 1) produced by the shaft-rider probe shows a 16 mil level of vibration. This measurement is highly reliable compared to the transient data obtained by the proximity probes installed by Steve.
2. The cost is only $900,000 compared to potential $19.5 million for Steve’s recommendation.
3. Employees might get hurt if the unit fails during a restart. The financial implications of this have not been included in the $19.5 million estimate.
4. Lucy has extensive experience working with coal-fired power plants.

Group 2: Assume the role of Steve and defend restarting the turbine-generating unit immediately.

5. Probes used by Steve provided more accurate measurements of vibration. A comparison of the actual Waterfall chart and that obtained from literature shows that an oil whip happened and there were no problems with the alignment or balancing of the shaft. Figure 2 shows the actual measurement that was recorded in complete lines and the expected measurement if there was an oil whirr in broken lines. Since the frequency was high at 0.5X speed and not at the 1X speed, it can be surmised that the vibration happened due to oil whirl.
6. The cost is $0.00 since no problems are expected at a restart.
7. The unit just came off a regular preventive maintenance schedule and there were no problems. Employees were well trained on safety measures.
8. Steve had intimate knowledge about the operation of the particular unit.

Group 3: Assume the role of Sam Towers, the plant manager, and decide between the two recommendations. Defend your answer and state how you used the information provided by the earlier groups.

9. If he chose Lucy’s recommendation, he would minimize safety concerns. But, there would be an unnecessary cost of $900,000. It would cut into the Operations and Maintenance budget.
10. If he chose Steve’s recommendation and the unit worked, Sam’s reputation would be enhanced. He would be appreciated for trying predictive maintenance methods.
11. If he chose Steve’s recommendation and the unit broke apart, his career with the company might be at stake.
12. A decision tree (figure 3) shows the probabilities so that the weighted costs of both recommendations are the same.

*Detailed essay answers to the questions are available from the authors.
Figure 2. Actual waterfall chart obtained from the probe.

Figure 3. Decision tree.

Group 4: Assume the role of a new technology group and discuss technologies that could be used in the future to solve such problems. Include measurement, data collection, information presentation, and communication issues.

13. Magnetic bearings could be used. Here suspension forces are generated magnetically without any contact. The advantages are: no mechanical wear, no lubrication, potential for high rotor speed, accuracy, and high dynamic performance.
14. Oil analysis might be used to check whether any metal particles were present.
15. A central database could monitor the performance data. An expert system could capture the plant-level decision-making thereby providing guidelines for the future.
16. Adequate time needed to be allowed for all components to reach their steady state temperatures before conducting tests.
17. Procedures to deal with such outages need to be changed. A dedicated high capacity telecommunications link could be implemented between the power plant and RLS Inc.,’s headquarters.
18. The quality of the charts produced by the equipment could be improved.

The students expanded these points and debated the alternatives in the classroom. The debates generated enthusiasm in the students and forced them to understand business issues. In seven classes where this case has been tried, five groups went with Steve’s recommendation, whereas two groups agreed with Lucy’s recommendation. Occasionally, some of the groups were challenged on their technical assumptions by their colleagues. Many students were able to use their past work experience in making the recommendations.

VI. EVALUATION BY STUDENTS

A common criticism of using new technologies for teaching is that their effectiveness is never measured. Therefore, the authors evaluated the effectiveness of using the Della case study by asking the students to complete a questionnaire.

A. Creation of a Questionnaire

A questionnaire was created to evaluate the effectiveness of the case study. The questionnaire included four measures: useful, attractive, clear and challenging. Each measure used multiple items in order to obtain properties of good reliability and validity. The property reliability requires that two different criteria be satisfied. The first criteria named Test-retest reliability means that the scale used to measure the responses (1 to 5) yields consistent measurements over time. The second criteria named Internal-consistency reliability means that when multiple items are used to create a measure, they will be similar and intercorrelate with each other. Validity is the property that ensures that the scale (1 to 5) is appropriate. The value for a measure was averaged from the values marked for items that defined that measure. It was important to compute a coefficient called Cronbach Alpha that shows how well the items coalesce to represent a measure. Many social scientists believe a Cronbach Alpha of 0.60–0.80 indicates that the items in fact represent the measure appropriately. Table 1 summarizes the items that were used for each measure and the value of the Cronbach Alpha. The values of Alpha were above 0.6 indicating that the items represented the measures reasonably well.

A questionnaire was created listing these sixteen items. The students were asked to evaluate the items with 1 for strongly agree, 3 for neither agree nor disagree, and 5 for strongly disagree. A lower value indicated a higher level of effectiveness. In addition, the students wrote written comments about the case study.

<table>
<thead>
<tr>
<th>MEASURES</th>
<th>ITEMS</th>
<th>CRONBACH ALPHA</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful</td>
<td>Useful, Important, Meaningful, Relevant</td>
<td>0.86</td>
<td>1.8</td>
<td>0.62</td>
</tr>
<tr>
<td>Clear</td>
<td>Clear, Easy to comprehend, straightforward, Well organized</td>
<td>0.76</td>
<td>2.5</td>
<td>0.73</td>
</tr>
<tr>
<td>Attractive</td>
<td>Exciting, Interesting, Lively</td>
<td>0.67</td>
<td>2.13</td>
<td>0.67</td>
</tr>
<tr>
<td>Challenging</td>
<td>Challenging, Brought real-life problems to classroom, Learned difficult concepts, Transferred theory to practice, Extraordinary, Sense of accomplishment</td>
<td>0.72</td>
<td>2.13</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Note: The items were measured on the Likert Scale of
1= STRONGLY AGREE 3=NEITHER AGREE NOR DISAGREE
5= STRONGLY DISAGREE

Table 1: MEANS AND STANDARD DEVIATIONS FOR THE 74 STUDENTS

Table 1. Means and standard deviations for the 74 Students.
B. Subjects
The subjects were 74 students in four sections of a mechanical engineering senior design project classes.

C. Results of Administering the Questionnaire
The responses to the questionnaires were received and entered into a database. All statistical analyses were performed using the SAS statistical software. First, each measure was tested to find out whether that measure was important to the student. This was done by comparing the mean of the measure with 3 (the response for neither agree nor disagree). T-tests were run to test the hypothesis whether the means were significantly different from 3. The results are presented in table 1.

The table shows that the means for each measure were significantly below the value of 3 at a level of 0.0001, suggesting that the students perceived that case study was effective on all the four measures. The students felt that the case study was really useful, attractive, challenging, and clear. This implies that the case study met its purpose of teaching important engineering-management issues to the students.

VII. REACTIONS TO THE USE OF DELLA CASE STUDY IN AN ENGINEERING CLASSROOM

We had major concerns whether the case study would be accepted by engineering students when we started this project. To our surprise, the students reacted extremely favorably and urged us to create more such case studies. We were also concerned that the engineers and managers in the company may not find time to work with us in developing such a case study. Contrary to our expectation, they were very cooperative and worked with us to enhance the students understanding of real-world experiences.

A. Student Reactions to the Case Study
The students found the case study to be beneficial to themselves, to the instructors, and to the companies. They commented:

I had Dynamics of Rotating Machines last quarter. I was able to tie in rotor dynamic concepts with actual application. It forced me to consider areas other than engineering consideration.

This case study was a good demonstration of the integration needed between engineers and managers. I have never worked in a similar situation and this was a good exposure to me on what to expect in a working environment.

The case studies should be used in most engineering classes as a possible substitute for the usual design projects. I think it would be more beneficial to do a case study that required the student to see the course material in a real-life application and not just a design for something that has no practical application.

B. Reactions of Power Plant Engineers and Managers
The engineers and managers at the power plant were enthusiastic in developing the case study for use in the classroom. They stated that they lacked such exposure to real-life problems while they were at school. An engineer stated:

When I went to school, I had never seen large machinery. I was surprised to see the size of a turbine-generator when I joined this power company. The use of case studies could provide the students a better understanding of the technologies used in our company.

The manager who sponsored this project was enthusiastic about developing the case study. He stated:

A good case study gives the students business aspects that you don't normally cover in engineering undergraduate classrooms. This experience is difficult for an average undergraduate engineering student because they don't have an equation to solve; there may not be one right answer in the case study. The value comes from evaluating the options presented in the case study, not from obtaining the "correct" solution. It gives the students a real-world feel of utilization of all the technologies. It gets the students excited and interested about learning engineering subjects.

The engineers and managers from the Power Plant were also eager to participate in the classroom discussions. The engineer
responsible for solving the problem came to the class twice and told the authors that he enjoyed being able to talk to students about problems faced in industry.

VIII. Creation of a Video

The authors created a video tape to provide an example of students discussing this case study. The engineer and manager from the company worked with the authors in producing this video. In addition, the students enthusiastically participated in creation of the video.

The pictures of the plant, turbine-generator, charts, etc., shown on the video were found to be very helpful in communicating the problem to subsequent groups of students. Also, the severity of the vibration was dramatized better by bringing a rotor kit to the same level of vibration as in the real-world problem.

IX. Implications for Funding Agencies and Educators

This project showed us that case studies need to be developed and used in engineering curricula. Our study showed that the case study was useful, attractive, challenging, and clear. The engineers at the company enthusiastically partnered in this project as they felt that they were contributing to the education of future employees.

Frequently, a perception by engineering faculty members about case studies is that it is a short write-up of an engineering problem that has a clear-cut solution. Involvement of a management professor in developing this case study brought in a cross-disciplinary approach to solving the problem. This case study not only discussed engineering issues, but also discussed the financial implications of the recommendation, credibility issues, and interpersonal issues. This problem did not have a clear-cut solution. When we administered the case study in the classroom, the students influenced the class to choose their option that was the other one. This closely reflects reality.

We found that developing and implementing this case study in engineering classes required substantial investment of time from the faculty members. The classroom experience for the faculty member was also more difficult and stressful, since the instructor was not in charge of the class continually. In view of the positive benefits of developing case studies, it is critical for industry and other funding agencies to encourage engineering professors to develop more case studies using the cross-disciplinary approach advocated in this paper. Such funding will make it possible to bring in the excitement and innovations happening in engineering industries to the classroom.

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References


