Introduction

Industry representatives stress that engineering education should give students impressions as to what life would be like in the real world and it needs to help them acquire competence in team building, interaction, and interdisciplinary skills (Klukken et al., 1997). The response of the engineering education establishment to these requests generally has been slow until recently. The ABET Criteria 2000 accreditation requirements for engineering programs show that future curricula will be strongly influenced by these industrial requests. Two recent studies by engineering educators, one sponsored by NSF (Shaping the Future, 1996), and another sponsored by National Research Council (Board on Engineering Education, 1995), both emphasize the need to move the curriculum in the direction that the industrial customers suggest.

Role of Case Studies in Engineering Curricula

During the phase I of this program, the panel speakers discussed the role of case studies in engineering curricula. Mark Walls, a panelist in that forum, eloquently summarizes the discussions as follows (Walls, 1999):

The seven SEATEC Forum papers expressed in many ways the ideal of a multidimensional, open-ended sort of case problem. The value of collaborative problem solving also was acknowledged by most writers. Most authors acknowledge a key need for interdisciplinary orientations of case problems. As

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Harvey Goodman notes, "Problems that workers generally face require them to synthesize their knowledge on a variety of subjects." Noting that no single definition exists for case studies, Professor Camerius cites a range of definitions, one of which claims a case is a "multifaceted investigation," and he later describes traditional case studies as "includ[ing] problems from many different fields . . . ." Elizabeth Mathias, with the SCANS 2000 project, states that "effective case studies should . . . draw knowledge and applications from many disciplines . . . ." and that SCANS 2000 module developers "found that students needed an array of academic knowledge to solve the problems" developed by the project. Similarly, Professors P.K. Raju and Chetan Sankar advise that technical case studies "integrate technical, managerial, and ethical issues," and they offer a student's positive comment that their Della Steam Plant case study "exposed [students] to other issues besides mechanical engineering . . . ."

Surely, it might be said, much of the "real-life context[uality]" (Camerius, Goodman), actuality or "realism" (Raju and Sankar), and "relevancy" (Mathias, Smith) advocated for case design goes far beyond verisimilitude for its own sake or just accurate recording of an historical case situation. What it is about the true accounting of a real-life case event that makes it so useful to learners is that an actual case likely reflects the "integration of broader aspects, including technical, economic, social, ethical, and environmental," one of Professor Smith's criteria for an effective case study. Ideally, I would maintain, a key goal of the case study is to produce in learners an expanded perception, an enlarged comprehension that transcends the immediate terms of some technical problem—whether simulated or actual. This seems most possible when the problem is multidimensional and crosses disciplines. Such interdisciplinary makes the case relevant and interesting to students. In no small part, it is what is "realistic" about a case and is, as well, what often gives a case its "open-ended" (Smith), "judgement"-oriented (Hornaday), "messy," "ambiguous" (Mathias) character. The point seems to me to be expressed by the engineering manager who sponsored Raju's and Sankar's Della Steam Plant case study project: "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."

In summary, a case study should develop the following skills in engineering students: teamwork, leadership, communication, and technical knowledge. In the next few sections, we share our experience in the use of case studies in engineering classrooms. Please refer to our earlier paper on details of the Della Steam Plant case study and our recommendation on the set of features that we believe need to be present in technical case studies (Raju and Sankar, 1999).

**Administration of case studies at Sophomore Level**

As we developed and tested the Della case study in the classrooms, we realized that creating a multimedia version of this case study might add to the learning experience of the students. Therefore, we created a multimedia CD-ROM that includes photographs
of the plant, equipment, competency material on power plants and vibration technologies, on-line references, problem statement, and the decision to be made by the manager.

The case study was administered over a 2-year period to teach undergraduate students in five sections of a mechanical engineering course. The students were divided into four groups. A group assumed the role of the manufacturer's engineer and another group that of the plant engineer and debated their recommendations. A jury group assumed the role of the plant manager and determined the final choice that needed to be implemented. A future technologies group proposed new technologies.

**Evaluation of Student Learning**

As part of evaluation of the effectiveness of the case study, the students in a ME sophomore level class, ME 260 (offered in Fall 1998) were given two separate evaluation forms at the end of the case study. The results in this section represent the reactions of the 23 students to the Della Steam Plant Case Study who used the CD-ROM in their discussion. Evaluation 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. Because the four constructs derived from Evaluation I yielded substantial reliability levels (with anything above .60 considered acceptable), the 24 separate questions within the survey could be meaningfully organized and reported by these four distinct descriptors of the case study. Table 1 shows the medians for responses on the four separate constructs.

Indeed, the medians for all four constructs are 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 two constructs with medians of 4.0, the students found the case study particularly important and valuable as well as relevant and useful--important elements in effective learning.

<table>
<thead>
<tr>
<th>Interesting and Exciting</th>
<th>Important and Valuable</th>
<th>Instructionally Helpful</th>
<th>Relevant and Useful</th>
</tr>
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<tbody>
<tr>
<td>3.4</td>
<td>4.0</td>
<td>3.8</td>
<td>4.0</td>
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**Table 1: Medians per Construct in Evaluation**

Evaluation 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 that represented the least positive or least favorable response of “Strongly Disagree” to a rating of 5 that represented the most positive or favorable response of “Strongly Agree.” In addition, Evaluation II ended with three open-ended questions that asked the students to provide written responses concerning the strengths and weaknesses of the Della Steam Plant Case Study as well. Substantial reliabilities for Evaluation II suggested specific constructs, which made an analysis of the data manageable and meaningful. The reliabilities are above the established criteria of .60 for all the constructs. The medians for these five constructs derived from Evaluation II are reported in Table 2.
Table 2. Medians for Constructs from Evaluation II

With the exception of Communication Skills, Table 3 illustrates that the reactions of the students to these various aspects of the Della Steam Plant Case Study were favorable. 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 would not report a change or improvement on this particular construct.

Table 3 summarizes how the educational objectives have been met based on the quantitative evaluations provided above and on the comments from the students (reported in Appendices A and B).

<table>
<thead>
<tr>
<th>Educational Objectives</th>
<th>How Della CD-ROM Achieved these Educational Objectives</th>
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<tbody>
<tr>
<td>The course material needs to:</td>
<td>-  Quantitative analysis (significant scores on constructs of interesting and exciting, important and valuable, relevant and useful)</td>
</tr>
<tr>
<td>- Connect engineering courses to real-world problems</td>
<td>- Appendix A provides supporting statements from students.</td>
</tr>
<tr>
<td>- Provide excitement of discovery</td>
<td>- Paper on the methodology won the outstanding engineering education paper (Raju and Sankar, 1997, Raju and Sankar, 1996).</td>
</tr>
<tr>
<td>- Motivate active learning</td>
<td></td>
</tr>
<tr>
<td>The course material needs to:</td>
<td>-  Quantitative analysis (significant scores on constructs of perceived skill development, intrinsic learning, self-reported learning, and learn from fellow students).</td>
</tr>
<tr>
<td>- identify criteria to solve problems in unstructured situations</td>
<td>- Appendix B provides supporting statements from students.</td>
</tr>
<tr>
<td>- analyze alternatives given multiple criteria</td>
<td>- The judges of the 1998 Premier Award commended it for its ability to improve higher-level cognitive skills (Raju and Sankar, 1998).</td>
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<tr>
<td>- make a choice and defend the choice persuasively</td>
<td></td>
</tr>
<tr>
<td>- be actively involved in learning situations</td>
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</tbody>
</table>

Table 3: Achievement of Educational Objectives by Della Case Study

Strategies to Use in Administering Case Studies in Engineering Classrooms
Based on our experience, we offer the following suggestions as strategies to use in administering case studies in engineering classrooms:

- **Case studies**
  1. The previous forum on Jan. 1999 suggests that there are not many technical case studies that could be directly used in engineering classrooms. It is critical that faculty members from the two-year institutions develop technical case studies. Our experience in this area suggests that these case studies will be meaningful if they relate to a problem that actually happened in an industry. Hence, the development of these case studies should be done in partnership with an industry.
  2. The quality of these case studies will be enhanced if they are subjected to peer review process in conferences and journals. We suggest that the technical case studies be peer reviewed and tested in classrooms before they become part of engineering curricula.
  3. Competency material relating to the needs of the case study be developed and shared with the students before they are assigned to analyze the case studies. This is different from the traditional case studies developed by business schools. Such a strategy is essential because of the multi-disciplinary nature of the real-world problems that are being addressed in these case studies. It is important to provide background material on the disciplines that have a significant role in the case study.
  4. Organizations need to be created that could be the repository of such well-tested case studies both at the regional as well as at the national level. Search schemes need to be implemented so that teachers can retrieve the case studies based on factors such as, disciplines addressed, topics, industry sector, geographical location, ratings, etc.

- **Student**
  1. Encourage the students to work in teams. Teaming exercises and guides might help improve group interaction.
  2. Provide opportunities for different students to lead the team for different case studies thereby providing opportunity for all students to participate in the discussion.
  3. Encourage teams to communicate with each other and the instructor. Tools such as electronic journals, e-mail, and chat rooms are very helpful in achieving this objective.
  4. Emphasize that you expect the students to carefully read the technical information in the case studies in order to analyze the problem.

- **Teacher**
  1. The teacher's role becomes that of a facilitator and not a leader of the class. This is rather difficult for most teachers, but requires practice before they can leave control of the class to the students. At the same time, the teachers have to be careful to ensure that the students do not steer the class into unrelated topics.
  2. The teacher has to encourage the students to perform group work. Reference to research material on group work might be helpful to the teachers.
3. A major issue is that of grading the presentation and write-up. The teacher has to create an evaluation formula that needs to be shared with the students. The clearer the teacher's objectives are to the students, the better the chances are that his/her expectations will be met.

4. It is critical to establish a mechanism to provide feedback to the students about their performance. Evaluation questionnaires similar to the ones we have used would provide valuable information on the utility of case studies in your classrooms. In addition, students could be requested to submit individual e-journals that document their progress on acquiring higher-level cognitive skills throughout the course.

- Administration

1. The administration has to be responsive to the use of case studies in the classroom. Since this is a new methodology, traditional accrediting agencies may not look at them favorably. An effective evaluation strategy that incorporates measurement of learning in the classrooms and reporting it to the administrator might be able to relieve the traditional biases against this methodology.

2. Educating the administrators about the value of the case studies in classrooms is essential if such a program has to succeed.

Conclusions

This paper discusses the strategies that could be adopted by instructors using case studies in engineering classrooms. An effective evaluation methodology is also outlined. It is critical that the results of the evaluation be used to improve the instructional methodology and delivery process. Technical education in two-year institutions could be significantly improved by the use of well-developed and tested case studies.

References


Appendix A: Student Comments on Della Steam Plant Case Study

Achievement of Goal I: Relevance of Engineering Education in Solving Real-world Problems

- The case study is a good use of a real problem for learning.
- It showed me a real world situation and was exciting to see if we made the same decision as the real engineers.
- The overall case study was helpful in bringing real world issues to the classroom.
- It's a good concept and a valuable tool for exposing students to real life engineering issues.
- It really happened. That fact that it wasn't made up and that I might be in Steve, Lucy, or Sam's place one day.
- Brought real world issues to the classroom. Informed me of real world situations.
- I have enjoyed working on an actual problem. This really keeps me interested because I see the theories that I learn in school applied in a practical environment.
- I learned about the many different risks that are involved in making decisions. It is helpful information to use when making any kind of engineering decision.
- These case studies make you feel more in touch with the engineering aspect of the world.
- Learning about the different problems that can occur in industry. One day I may be faced with one of these problems, now I'll have some idea of what happens next.
- It was about the power industry. A lot of jobs are in the power industry so it is good to have some knowledge of the problems that can be encountered.
- It brings a practical situation in to train us to think in a professional manner.
- Based on this case study, I would make a good engineer.
- As an engineer, I feel that I am one step closer being able to make real-world decisions. This is exciting when preparing for the future.
- I feel that doing these case studies helps us prepare for the decision we will have to make in the future.
- I enjoyed finally seeing all of what we have been studying put to practical use. Spending too much time in the theoretical area makes me feel like a scientist and out of the world I am living in. I'm not a scientist, I'm an engineer, and I'm concerned with real world situations and practical application.
- I learned more about turbines in this case study than I did on a tour to a steam plant years back.
- I enjoyed working with a real life engineering problem. I want to see what I will be doing in the future and not have to work problem after problem without seeing the point. I personally think we should have more classes such as this one offered to the students.
- I enjoy learning about real world experiences in the classroom.
- I have enjoyed working on an actual problem. This really keeps me interested because I see the theories that I learn in school applied in a practical environment. I also enjoy the simulated responsibility of studying the problem from different points of view, and from the information given, generating questions and at least forming a personal opinion on how the situation should be handled.
Appendix B: Student Comments on Della Steam Plant Case Study

Achievement of Goal 2: Development of Higher-level Cognitive Skills

• I was allowed to think, analyze and make a decision on my own and within a group.
• It provides many different aspects about decision-making in financial, technical, safety.
• I believe that the most enjoyable aspect to the case study is the group work that is involved with case study participation.
• Division into groups to analyze or defend different aspects of the problem was a good idea.
• The case was clear in that it defined the problem, possible solutions, and consequences of these solutions well. It also required us to weigh each possibility with each outcome to reach a decision.
• I think that I am better thinker, planner, and problem solver because of these case studies.
• I learned that I think along the lines of a problem solver better than I thought I did.
• I brainstormed for ideas, then I decided which options were feasible and which were not. I also decided to place more emphasis on the long-term goals of Crist.
• I practiced breaking down a problem situation and looking at all component aspects of the problem including costs vs. risks, materials available, and use of resources to make an intelligent decision on how to treat the situation at hand.
• Each person had various views as to which decision should be best. The views were presented and we considered their pros and cons. We engaged in valuable discussions where significant points were mentioned that I did not know.
• I can see myself using the cost and risk factors in the future along with the software programs for the evaluation of this data. I learned that it is important to completely explore all possibilities and not to eliminate them before I am completely sure they should not be considered.
• I learned that in most case there is never a definitive a best option for any given situation. This made me realize that it is very important that I learn how to make big decisions and have evidence to back up my decision.
• The team discussion was both productive an insightful. By pooling the perceptions and thoughts of several different people, we were able to come up with a more comprehensive argument. All team members worked well together, and there was an equal sharing of communication and effort.
• I learned how to implement group problem-solving strategy and how to research the technical aspects of studies. I feel better prepared having actually participated rather than just listening.
• Once I started analyzing the situation I felt as if I was the engineer involved in the problem. I was impressed that having a little guidance into what my future holds actually made me feel and think, as an engineer should.
• I noticed that this one case actually helped me analyze my thought processes. I feel that my problem-solving methods have become more keen. I was assigned a task and concentrated on that one particular aspect and its effects on the other components of the problem. This problem interested me and therefore I gave it all of my undivided attention.
• I think I’m a better thinker, planner, and problem solver because of these case studies.