2006-1260: IMPLEMENTING A MULTI-MEDIA CASE STUDY IN A TRADITIONAL LABORATORY CLASS

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Implementing a Multi-Media Case Study in a Traditional Laboratory Class

Abstract

A paradigm shift is taking place in engineering and technology education. The shift is driven by emerging knowledge related to cognitive theory and educational pedagogy, information technology, the National Science Foundation, the Accreditation Board for Engineering and Technology Education (ABET), the changing expectations of employers, and many other forces. Within the new paradigm, instructors are expected to harness students' prior experiences, promote high expectations within a supportive climate and encourage inquiry and the excitement of discovery, in addition to embedding communication and teamwork, critical thinking, and life-long learning skills into the learning experience (National Science Foundation, 1996). Active, integrative project-based learning is needed to replace the passive lecture-based instruction that is so common in our classrooms.

Realizing the importance of addressing these requirements, Drs. Raju and Sankar at Auburn University, AL, formed the Laboratory for Innovative Technology and Engineering Education (LITEE) in 1997. Through their preliminary research they and other researchers have shown that case study methodology was a very good candidate for meeting the educational objectives under the new paradigm. Case studies have been used extensively in business, medicine and law curriculum across the country but have never been effectively used in teaching engineering in the past. In an effort to change this, LITEE developed several multi-media based case studies using actual industrial problems with all the nuances, conflicts, and issues built in. These case studies are not course specific but have elements of many fundamental engineering science courses, business and finance aspects, as well as communication, ethics and interpersonal issues. One of these case studies was adapted and used in a Mechanics of Materials laboratory class as a pilot study on the effectiveness of the use of such a technique. In this paper the pilot study and its results are being discussed .

Introduction

A paradigm shift is taking place in engineering and technology education. This shift is being caused by a number of forces. The National Science Foundation (NSF), the Accreditation Board for Engineering and Technology Education (ABET), the changing expectations of employers, emerging knowledge related to cognitive theory and educational pedagogy (such as the document "How People Learn"[1]) are some of the forces that are altering engineering education dramatically. The new approach assumes that every student can learn with the assistance of effective new strategies and practices that increase learning. Instructors are expected to build on the students' prior experiences, promote high expectations within a supportive climate and encourage inquiry and the excitement of discovery. All these need to happen in addition to embedding communication and teamwork, critical thinking, and life-long learning skills into the learning experience. As a result, active, integrative project-based learning activities are replacing the passive lecture-based instruction that is so common in many of our classrooms[2].

Engineering students are increasingly being asked by potential employers to demonstrate soft skills (such as problem solving, business skills, etc.,) in addition to hard technical skills. Faculty members at many universities are beginning to address these concerns by integrating new instructional materials and practices into their curricula. There is also a growing realization among educators of the need to put a greater emphasis on imparting higher-level cognitive skills (e.g., reasoning, critical thinking, decision making, problem identification, and problem solving). Research shows that higher-level cognitive skills can be improved by training, and it is not safe to assume that such skills will emerge automatically as a matter of development or maturation.[3]

A review of literature reveals that the teaching methodologies of lectures, experimental laboratories, design projects, case studies, games, and internships are all likely to achieve the requirements but the case study methodology is the best candidate for meeting all the educational objectives.[4,5] In disciplines such as law, medicine, and business case studies have been very successfully used to teach fundamental concepts and their practice. The same has not been true for engineering.

Realizing the importance of addressing this need for using case studies, Drs. Raju and Sankar at Auburn University, AL, formed the Laboratory for Innovative Technology and Engineering Education (LITEE[6]) in 1997. LITEE obtained funding from NSF and other sponsors to develop award winning case studies that could help faculty members make the necessary paradigm shift in engineering and technology education. The case studies are based on real-world engineering problems that have engineering issues intertwined with business aspects, ethical questions, communication, etc. Their case studies are not only rich in content but are also very professionally compiled with full use of currently available multi-media technology.[7,8,9] These case studies are available on CD–ROM along with all necessary background information, linkages to scientific topics, all the video and audio files, proposed student assignments, and lesson plans for teachers.

Drs. Raju and Sankar used these case studies in many of their classes and published their findings in conferences and journals.[7,8,9,10,11] During 2001-2003, they developed four pilot workshops with partial support from the National Science Foundation to provide faculty with an opportunity to gain hands-on experience with the use of their multimedia case studies. I attended two of these workshops and adapted many of their case studies for a graduate course on "Design Case Studies." The course was quite successful and the students commented very positively about the unique structure of the course. Subsequently, I chose the Della Steam Plant case study for implementation in an undergraduate Mechanics of Materials Laboratory class. This paper discusses my experiences with that effort. The modest goal of this effort was to determine the effectiveness of the case study as a teaching tool, i.e. try and find answers to the following questions:

- Is the case study a more effective learning tool than traditional lecture, HW, etc.?
- Does a realistic case study motivate students to take on the learning responsibility?
- Does it help them realize the importance of life-long learning?
- Does it help them do better at teamwork and communication?
- Does it help them in exercising and improving their critical thinking skills?

Structure of the Mechanics of Materials Laboratory Class

The Mechanics of Materials laboratory class is a one credit required course for both Mechanical and Civil Engineering students in our program. This course is a co-requisite of the Mechanics of Materials lecture class. The experiments conducted by students are no different from a similar class in a different program and follow the general theme of structural property determination of different materials. There are nine different laboratory experiments that are conducted over 14 weeks. Several years ago, in order to add some more (and perhaps, more interesting) activities to the curriculum I introduced case studies in this course. For the last 3-4 offerings students did a case study assignment as the first activity in this course. This assignment usually was spread over two weeks. The class was divided into groups of three and each group was assigned to research a well-known case of engineering failure. During the following class period each group made a presentation on their particular engineering case and also did a critical analysis of what happened, the causes of failure, how the failure could have been avoided, ethical issues, etc. Some of the cases considered over the years include:

- Kansas City Hyatt-Regency Walkway collapse
- TV antenna disaster in Houston
- Ford Pinto
- Challenger Shuttle Disaster
- L'Ambiance plaza collapse
- ThreeMile Island
- Columbia Shuttle
- Quebec Bridge
- Ford/Firestone Tire recall
- Columbia Shuttle Disaster

These case studies exposed the students to facts about engineering in the real-world and were especially effective in showing them that real-world problems comprises of not only individual disciplines of engineering but ethics, communication, business, politics, and legal aspects. During these case study assignments I also observed that student enthusiasm was much higher than during more traditional activities such as conducting routine laboratory tests and writing reports.

Description of the Della Steam Plant Case Study (as per the CD)

Like all other case studies developed at LITEE this one is based on an actual incident that occurred in industry. At a thermal power generation plant located in the South East of US there was an incident related to extreme vibrations in a turbine generator (Figure 1). Observing these vibrations, and having looked at some of the available data obtained from on-line sensors, one engineer recommended that the generator be shut down, taken apart, and inspected for possible problems and damage. Another engineer concluded that the vibration is due to a phenomenon called "oil whip" and will go away once the lubricating oil warms up. His recommendation was to restart the generator. The plant manager was in a dilemma. The two opposing recommendations had risks associated with them. Also, he had to worry about safety, liability and company profit (and loss) in a very competitive and deregulated power industry. The description of the actual case is given below along with some of the actual charts and figures that the engineers involved in this case used. Figures 1, 2, 3 are three pictures taken from the case CD. These three pictures give some idea of the power generation unit, the rotor and some of the vibration measurement probes. Figures 4, 5, 6 are the actual charts that the engineers in this case worked with to determine what went wrong in the system. These charts are not poor reproductions of better originals. These are the originals. Looking at real data from a real situation is extremely beneficial for the students. Although one can complain about the quality of these, one has to accept the fact that real world is imperfect.

Figure 1: Turbine Generator

"Sam Towers, plant manager of Della Steam Plant, had no hesitation in shutting down the turbine-generator unit (Figure 1) based on the recommendation of Lucy Stone, the manufacturer (RLS) representative, and Bob Make, the day shift maintenance engineer. Lucy Stone ran an overtrip speed test on a turbine-generator unit that was restarted after a two-month preventive maintenance overhaul. The unit began to vibrate heavily and caused the building to shake. An overspeed trip mechanism attached to the turbine-generator tripped causing the unit to coast down to a stop in the next few minutes. Many employees were scared and started moving away from the unit. Everyone around the turbine thought that it was going to come apart. Lucy Stone studied the vibration chart produced by the shaft rider probe (Figure 4) attached to the turbine generator unit. The chart showed that it was a 17 mil (one thousandths of an inch) vibration level and she felt it was too near the 22 mil clearance between the shaft and the bearing. She recommended to Sam Towers that the unit be torn down and inspected thoroughly. She expected that the retainer rings might have to be replaced.

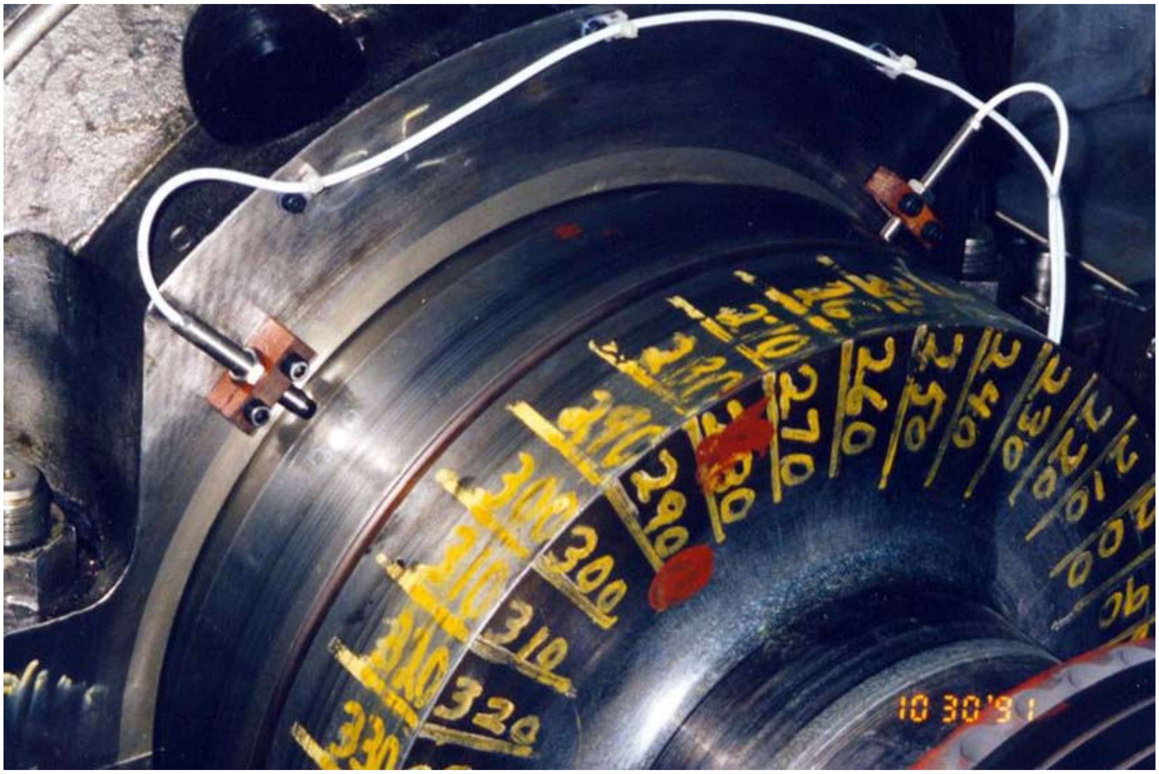

Figure 2: Close-up of the rotor showing the proximity probes

Bob Make, the day shift assistant maintenance engineer at the plant, looked at the charts produced by the proximity probes (Figure 2) that Steve Potts, his supervisor, had installed on the turbine-generator as part of predictive maintenance practices. The dotted lines on the figure showed a 17 mil vibration level and he agreed with Lucy that the plant be shut down and inspected thoroughly. Sam Towers agreed to the two recommendations and requested the maintenance workers to tear apart the turbine. He was aware that it would cost approximately $900,000 (Table 1) for the unit to be out of operation for a week.

Steve Potts, the engineer in charge of predictive maintenance at Della Steam plant, had gone home at 6 a.m. after the unit was started and became operational. He woke up at 1:00 p.m. and called Bob Make, his subordinate, to check the status of the unit. Steve was surprised to learn that the unit had been shut down and wanted Bob to look at other charts produced by the proximity probes.

After arriving at the plant, Steve looked at the charts that track the overall vibration level and the vibration level at the running speed of the turbine generator at 7.56 a.m., the time the vibration started. He noticed that the vibration level at the running speed (1X speed) indicated by the solid line in Figure 5 was only 3 mils. Figure 6 showed that the high vibration level occurred only at a frequency of 1,000 cycles per minute (kcpm) and not at the running speed of 3,000 cycles per minute. Based on these data, Steve surmised that the vibration occurred due to oil whip. He concluded that Lucy should have waited for 24 hours for the oil to heat up before running the overspeed trip test. He recommended to Sam to restart the unit immediately since the vibration problem was due to an oil whip and save $900,000 by avoiding an unnecessary shutdown.

Figure 3: Dismantled Turbine generator unit

Sam pointed out that there were risks in accepting Steve's recommendation. The costs might be as high as $19.5 million if the unit failed during restart requiring a replacement (Table 2). It would also take six months to get a new unit to work. There were also safety concerns regarding injuries to personnel if the unit broke apart during restart.

Sam was in a dilemma since, in the past, the plant engineers had always agreed with the recommendation by the RLS engineers. This was the first time Steve had not agreed with Lucy and created a dilemma. Sam felt that the top management would endorse the decision to restart the turbine-generator unit since they had decreased the maintenance budget for the next five years and were forecasting a further reduction. If Steve's recommendation was successful, Sam would be considered a capable leader who was willing to try innovative tools. But, if the unit broke and employees got injured, the top management would point at him as the person who made the decision to restart the unit in spite of Lucy's recommendation. Sam realized that he had to examine carefully the technical data and make his decision based on technical, financial, and safety aspects. He called for a meeting of Steve, Lucy, and Bob in order to arrive at the final decision."

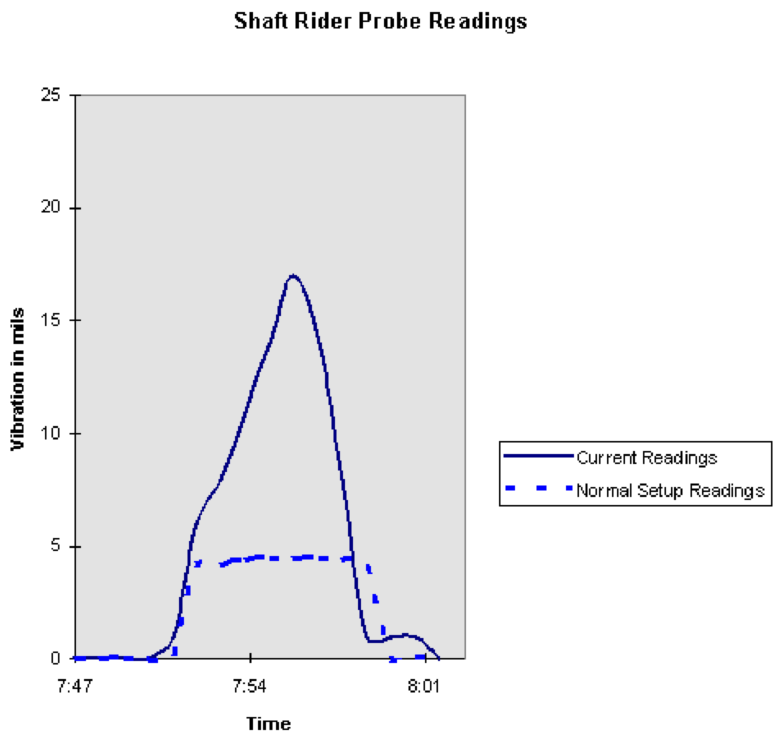

Figure 4: Shaft Rider Probe Data.

Table 1: Financial Implications of Recommendation 1, Stop Unit and Fix Problems	
(1) Cost of operating this unit per day:	$100,000
(2) Cost of operating a peak unit per day:	$200,000
(3) Excess cost of operating a peak unit instead of unit #9 per day = (Row 2 - Row 1):	$100,000
(4) Number of days unit #9 will be out of operation:	7 days
(5) Excess cost of operating a peak unit for 7 days: = row 3 * row 4	$700,000
(6) Labor and material cost to fix unit:	$200,000
(7) Total cost if this recommendation is followed: = row 5 + row 6:	$900,000

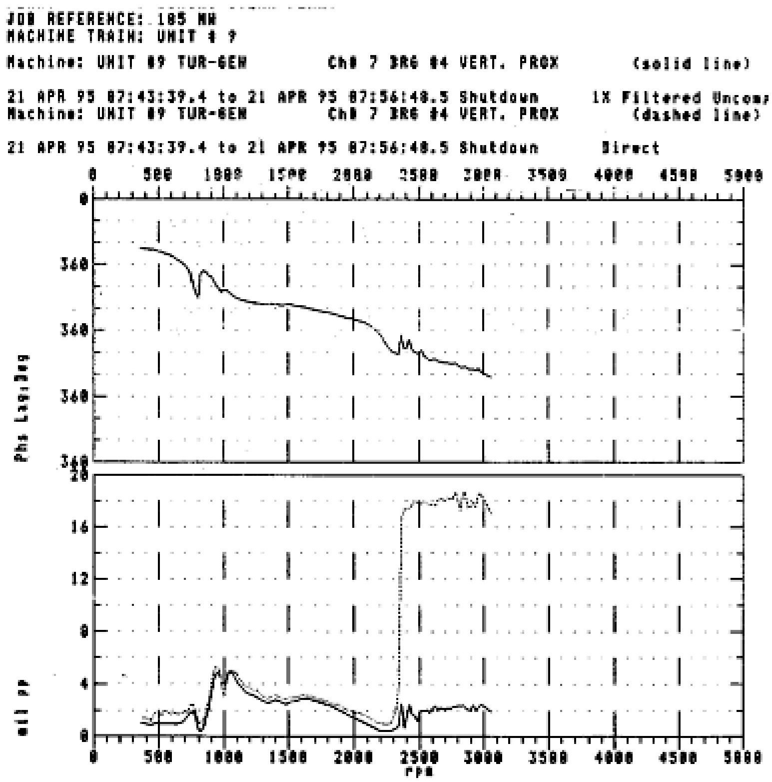

Figure 5: Proximity Probe Data.

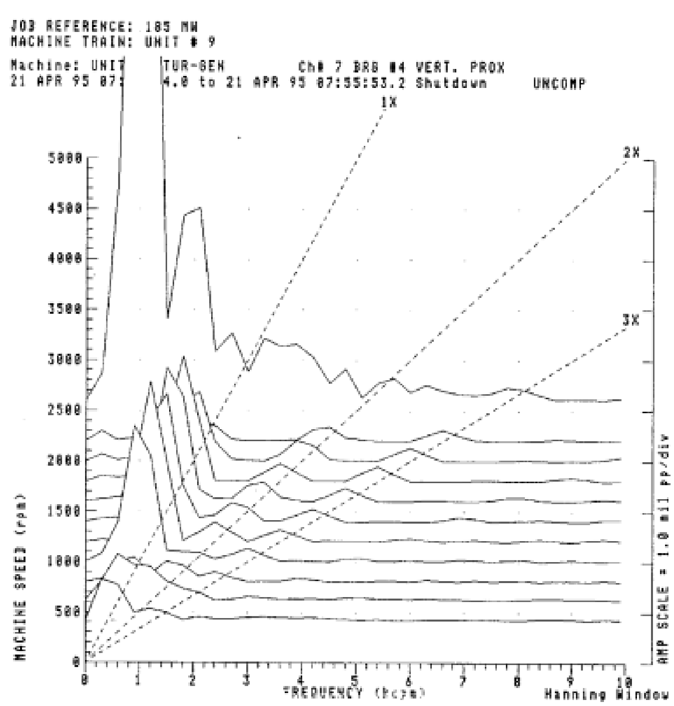

Figure 6: Waterfall chart from proximity probe data.

Table 2: Financial Implications of Recommendation 2: Restart the Unit Immediately	
Alternative (a): Unit worked well; No failure	
(1) Excess cost of operating a peak unit per day instead of unit #9:	$100,000
(2) Number of days for which the unit failed:	0 days
(3) Total cost if this recommendation is followed: row 1 * row 2:	$0.00
Alternative (b): Unit failed, new unit ordered and installed	
(1) Cost of operating this unit per day:	$100,000
(2) Cost of operating a peak unit per day:	$200,000
(3) Excess cost of operating a peak unit instead of unit #9 per day: = row 2 - row 1:	$100,000
(4) Number of days unit #9 will be out of operation:	180 days
(5) Excess cost of operating a peak unit for 180 days = row 3 * row 4	$18 million
(6) Cost to buy a new unit:	$ 1 million
(7) Labor and material cost to install unit #9:	$0.5 million
(8) Total cost if this recommendation is followed: = row 5 + row 6 + row 7:	$19.5 million

Implementation of the Della Power Plant Case Study

Since there was a history of using case studies in this class implementation of the Della Power Plant case study was not very difficult. The objectives (as stated earlier) for using this case study were to determine the following:

- Is the case study a more effective learning tool than traditional lecture, HW, etc.?
- Does a realistic case study motivate students to take on the learning responsibility?
- Does it help them realize the importance of life-long learning?
- Does it help them do better at teamwork and communication?
- Does it help them in exercising and improving their critical thinking skills?

To achieve these objectives several steps were taken. First, the students were given a list of terms from the glossary of the case study and were asked to read their definitions carefully for the following class. They were also told that they would have to answer quiz questions on these terms. In the following class, they were given the same list of terms and asked to explain the meaning of each. The terms from the glossary were:

- Bearings
- Clearance
- Infrared thermography
- Megawatts
- mil
- Motor current analysis
- Predictive Maintenance
- Preventive maintenance
- Transient data

This quiz was conducted to find out how well they learned in the most traditional form of learning (i.e. they are given a list to look through, without any context being provided and they are tested on how much information they could retain). The quiz, as can be seen here, was very rudimentary and the average score in the class was 91%. After taking the quiz the students were given a half hour introduction of the case using the CD-ROM. In this introduction the main highlights of the case were explained. Students were also shown that the CD contained that a lot more information that they will have to go through on their own. There were two sections for this class that met at different times with about 8/9 students per section. Each section was divided into three groups and they were given the following assignment:

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

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

Group 3: Future Technologies Group: Assume the role of 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. (obviously, with the measurement technology the plant had confusions as identified in the case here could happen again and should be avoided)

All the groups were given a week to research the case and prepare their presentation. During the following class period each group made their presentation that was followed by a discussion of the presentation including questions and answers. After all the presentations were made the whole class was asked to assume the role of the plant manager and decide the final course of action based on evidence provided in the presentations. At the conclusion of the exercise the students were told what Sam Towers eventually did during the real event. In case of both sections the class came to the same conclusion as Sam did during the real event.

Following the presentations a second quiz was given to the students. This was an unannounced quiz in which they were asked to explain the meaning of some engineering terms that they encountered in the case. Since the quiz was unannounced none of the students got a chance to prepare separately for the quiz. Thus, they were tested for what they learned by preparing for and participating in the case study assignments. The terms that were on this quiz were:

- Predictive Maintenance
- Preventive maintenance
- Turbine-generator
- Overspeed trip test
- Oil analysis
- Shaft rider probes
- Eddy-current proximity probes
- Oil whip
- Corrective maintenance
- Infrared thermography

The average score of the class was 90% in this second quiz. After the conclusion of the quiz the students were also given a written survey with 7 questions that everyone completed.

Assessment

There were several tools used to assess the outcomes of this exercise. Some of them were qualitative and some were quantitative. The results from the pre- and post-quizzes indicate that by participating in the case study assignment the students learned at least as well as they did in the more traditional way (i.e. read and prepare for a quiz).

During the discussions I sat quietly in a corner and allowed the discussion to take its own course. From time to time I asked one or two probing questions to move the discussion along. I made many observations of student behavior that can be used as qualitative evidence to prove the effectiveness of the case study. While the students were participating in the case study assignment the level of enthusiasm was extremely high. There were long heated arguments, especially amongst students representing opposing viewpoints. Lucy's group challenged Steve's group and vice versa on several occasions. The students used hard facts, data, and its interpretation to make the case to each other. Many student groups used sources other than the CD-ROM (i.e direct case information) to strengthen their argument. For a change, the students were very active and the instructor could afford to be passive.

The survey answers were very useful to get insight into how the students perceived the exercise. I chose not to use a standard 1-5 scaled survey because I wanted to find a little more information than just "agree" and "disagree" type of answers. However, to keep the survey short only 7 questions were asked. The survey responses indicate that the students viewed this exercise with practically 100% satisfaction. All the questions asked and the answers received are listed below.

Student Survey Results

The questions on the survey and a compilation of answers are shown in the table 3 below:

Table 3:Survey questions and answers	
Survey Question	**Answers**
1. Name a new concept (or concepts) you learned from the case study?	Oil Whip; Proximity probes; 3D modeling; how turbines warm up; vibration analysis; monitoring systems; how poor communication can have a snow-ball effect leading to serious problems; over speed trip test; turbine operation.
2. Was the case study realistic?	All the students felt that the case study reflected reality.
3. You were assigned to play a role. Has this helped you to learn more than you would have if no role-playing was involved?	Yes, because it forces us to look at the entire case study and thus we learned more. If I did not play a role I would not have been so involved. It helped me gain knowledge as I completed my research and analyzed what the issues were. Playing the role made me look at the graphs and charts more in-depth so that I could prove oil-whip. Because I had to study both sides of the argument and a lot of data. I imagined myself in the situation, defending a position; this enabled me to learn more.
4. Put yourself in Sam Towers' shoes, what would you have done? Will your conclusion be any different if we tell you that fictitious names were used and both Lucy and Steve were men.	Everyone said that they would have looked at the evidence and the gender of the engineers was not an issue at all.
5. Compare this assignment with other routine assignments you receive in most courses. Was you motivation increased, decreased or about the same to work on this real world case study?	Increased: Because the competition aspect made this more interesting. Because it was a real situation. Because it allowed me to come up with a solution for a real-world problem. Because I wanted to present our views as well as possible. Because it was a real life situation and the competition with other groups made it fun. Because it was a debate. Because it was enjoyable and informational. Because I so-oped at DTE energy and worked in power plants; I was familiar with the topic because problems like these are common. Motivation remained about the same.

6. Name all the sources you used for information (e.g. internet, case CD, any other, etc.)	Case CD and few websites. Internet and personal contacts at a powerplant in Pensacola, FL. Contacted personnel in a DTE power plat where I had been a co-op last term.
Two important learning related terms are very relevant for today's world. *Life-long learning:* continue to learn even after you leave school (on the job etc.) *Self-directed learning:* seeking out information on your own and determining what is needed to be learned 7. After working on this case study: • Has your appreciation for life-long learning increased, decreased or remained the same?	Most students said "increased". Some said "remained the same." Some gave reasons such as: Increased because you do learn things in the field that you don't learn in school.
• Has your appreciation for self-directed learning increased, decreased, or remained the same?	Most students said "increased". Some said "remained the same." Some gave reasons such as: I really didn't like researching too much but it was exciting in this case to find something that needed a solution. Increased because it helps define my diagnostic skills.

Discussion and Conclusion

Although case studies have been successfully used in Law, Medicine, and Business curriculum the use of case studies in engineering is not as common. Drs. Raju and Sankar developed some excellent multi-media based case studies that can be used in engineering courses very effectively. The case study CDs and supporting written documents are very elaborate with videos, pictures, and cross-references to basic concepts in engineering and science. The student exercises are designed such that the students can assume the role of one of the characters in the case. This ensures that students get very involved in the case situation. This "immersion" in a real world engineering problem generates a lot of enthusiasm towards the subject.

During the implementation of a case study in a course it was clear that the students were overwhelmingly positive about this exercise. A simple quiz showed that learning of information and concepts happen at least as well as in a more traditional approach. In preparing for the presentation of the assignment the students used web tools, CD-ROM, and even called and interviewed actual power-plant operators to gather information on the subject. This clearly indicates that they have learned to harness some of the self-learning skills that will be useful for life-long learning. The presentations were done professionally, the analysis was critical, and students challenged each other. Post-presentation discussion was also very animated indicating that the students chose to immerse themselves in the assignment. The level of involvement observed in the students was very refreshing. This adaptation and implementation exercise was a very satisfying and successful experience.

An exercise to be carried out in future will be to use this or another case study to introduce a topic of engineering (e.g. thermodynamics) at the beginning of a course. And then use the case as a background to teach the content of the engineering topic as and when it is needed in the case study. The results obtained from such a teaching method could be compared with results from a more traditional teaching technique. The data available from such a study may be more useful in showing the importance of using cases to teach deeper technical concepts.

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