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An Innovative Teaching Method to Improve Engineering Design Education[1]

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Introduction

Industry representatives stress that engineering education should prepare students for real-world problem-solving situations. They expect students to be provided opportunities to acquire competence in team building, interaction, and interdisciplinary skills during their college education. 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, sponsored by National Science Foundation and National Research Council, emphasize the need to tailor engineering curricula to meet industry requests. A review of various instructional methodologies to fulfill these industry needs identified the case study method as the most suitable instructional technique to achieve these educational objectives. Therefore, an inter-disciplinary team of engineering and management professors developed a series of case studies and used it in a sophomore level mechanical engineering design course. Two professors from education developed an assessment process and evaluated whether the course met the objectives.

This paper describes the objectives and design of the course, implementation in a mechanical engineering classroom, and evaluation of the effectiveness of the course in achieving the objectives. We also show how adaptation of the materials used in this course could help realize many of the ABET 2000 criteria.

ABET 2000 Criteria

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[1,2]. 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;

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(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.

Goals and Educational Objectives

We designed an engineering design course to meet many of the ABET 2000 criteria and achieve the following goals and educational objectives.

The first goal of this course was to bring theory, design, and practice together. The educational objectives were that the students must (a) understand basic engineering design concepts and decision-making concepts; (b) consider technical, financial, credibility, and management issues in making decisions; and (c) work in teams and learn from each other.

The second goal of this course was to develop students' higher-level cognitive skills. In order to achieve this goal, the educational objectives were that the students must (a) identify criteria, (b) analyze alternatives, (c) make a choice, (d) defend the choice, and (e) be active learners.

Methodology

After an evaluation and pilot testing of various instructional methodologies, the engineering-business team chose the case study method of instruction as the appropriate one for use in this course[3]. The instructional methodology consisted of (a) developing a series of written case studies to meet these objectives in conjunction with industry partners; (b) providing competency material on related engineering, design, decision-making, ethics, and business topics; (c) enhancing the written case studies by multimedia supplements; (d) developing a monograph that included all the case studies and competency materials; (e) administering the case studies in an engineering classroom; and (f) evaluating the effectiveness of the case studies in achieving the goals and objectives of the course as well as ABET 2000 criteria.

<u>Developing a Series of Case Studies:</u>

The first case study, *Della Steam Plant*, was developed with the cooperation of an executive in charge of predictive maintenance at the central office of a power plant. Data were gathered through visits at the plant and interviews with engineers. They were integrated together with the technical, financial, people, and risk information in order to create a draft of the case study. After the engineers and managers from the power plant reviewed and revised the case study, it was further improved based upon feedback obtained from conference presentations, classroom discussions, and publication in a refereed journal[4].

The second case study, *Crist Power Plant*, dealt with the cost and risk issues faced by a plant manager when he had to decide between five alternatives in maintaining a turbine-generator unit. Expert system software was used to analyze the decision-making strategies of these engineers. The case study was pilot tested in engineering and business classrooms and improved based on student feedback. It was further improved when it was published in a refereed journal[5].

The third case study, *Solid Rocket Booster Field Joint Design*, illustrates the ethical, safety, reliability, risk, schedule, and cost factors that were involved in the field design of a solid rocket booster. Students were given an opportunity to develop alternate designs of the field joint and identify the ethical issues that arose as time and cost pressures forced the engineers to choose between the options of adding shims and doing a complete redesign. This case study was further refined by being presented to NASA engineers and being reviewed for a conference presentation[6].

All these case studies were developed by an interdisciplinary team of students (undergraduate, graduate, and doctoral) and faculty members from the Colleges of Engineering and Business as part of a National Science Foundation project. They interacted extensively with managers and engineers from industry in order to ensure the accuracy of the materials.

Adding Competency Material:

Competency material chapters were developed in order to help the students analyze the case studies on topics such as decision-making, design, power industry overview, and ethics. The materials were developed to be understood by prospective engineers from any engineering discipline. In order that students with limited background about the power plant industry and technical topics discussed in the case study could effectively analyze the *Della Steam Plant* and *Crist Power Plant* case studies, competency materials on the topics of vibration analysis, predictive maintenance, decision theory, and power plant economics were developed. Similarly, competency materials on engineering ethics and engineering design were developed for better understanding of the *Solid Rocket Booster Field Joint Design* case study.

Creating Multimedia Supplements for the Case Studies:

The final version of the *Della Steam Plant* written case study and its competency material became the basis of a CD-ROM courseware that formed a supplement and included videos, photographs, and text. The case study methodology and associated CD-ROM for the *Della Steam Plant* case study was selected as the winner of the 1998 Premier Award for Excellence in Engineering Courseware sponsored by John Wiley and Sons and NEEDS (a NSF coalition). The judges lauded the ability of this courseware to develop higher-level cognitive skills.

Two videos were created to support the *Crist Power Plant* case study. A web site and video were developed to support the *Solid Rocket Booster Field Joint Design* case study. About 180 students in engineering and business programs have participated in analyzing the case studies at Auburn University, Alabama A&M, University of Pittsburgh, and Embry-Riddle University during 1997 to 1999. Based on their positive feedback to the case study administration, we developed a ME 260 (Concepts in Engineering Design) course based fully on the case study methodology.

Developing a Monograph:

Each student was provided a monograph during the course and it included all the case studies, competency materials, and multimedia supplements. This monograph was designed for an instructor to use in either a semester or a quarter system.

The monograph was divided into five parts. Each part had initial chapters that provided the technical and business competency material useful in analyzing the case study. An instructor could teach the competency materials in a few classes. The second portion of each part contained case study(ies) that dealt with the topic. The instructor could assign these case studies to student teams for analysis and presentation.

Part I introduced the concept of case studies and helped the students understand how to analyze each case study. It included a chapter that presented theories on decision making and provided tools that could be used to analyze, prioritize, and make decisions. Part II covered topics in vibration analysis and included two case studies that discuss problems that occurred in two steam power plants. Two chapters provided information on the power industry and maintenance practices. Part III covered topics in engineering design, ethics, and included two case studies that discussed the options in the design of a solid rocket booster. Part IV covered topics in telecommunication networks and included a case study that shows how a small company used satellite technologies to conduct on-line auction. Part V concluded the monograph. The parts were designed so that it is possible to skip a part without losing the flow of material. The materials were chosen so that the difficulty of the material flows from simple to complex topics.

Part I, Chapter 1 introduced the monograph and provided an overview of the key topics to be discussed and explained the case study method of instruction. Chapter 2 discussed the theories on decision making and explained a few decision models. It described decision trees and Decision Support Systems. In particular, it detailed *Expert Choice*, a Decision Support System based on Analytic Hierarchy Process.

Part II, Chapters 3 and 4 provided the business and technical information needed to analyze the case studies presented in this part. Chapter 3 discussed the dynamics of deregulation in the power industry and provided a macro-economic view of this industry. Chapter 4 discussed the maintenance practices that were used in industry and described fundamentals of vibration measurements. Chapters 5 and 6 detailed two case studies. Chapter 5 described the Della Case Plant case study. This case study asks the students to assume the role of a plant manager and decide on an option when two engineers have conflicting recommendations. Chapter 6 described Crist Power Plant case study and asked the students to assume the role of plant manager and pick an option that could be used in maintaining a turbine-generator unit at Crist Power Plant.

Part III, Chapter 7 discussed the fundamentals of ethics and how it applies to engineering discipline. Ethics codes from the different professional societies were also provided. Chapter 8 provided the fundamental factors that need to be considered in engineering design. Chapter 9 provided a technical overview of the Solid Rocket Booster. Chapter 10 discussed the decision facing the design engineers working for NASA and MTI in choosing a complete redesign versus partial redesign for the solid rocket booster field joint. Chapter 11 explained the testing and design decisions adapted by MTI and NASA during the 1980s. The students were asked to decide whether or not NASA should launch the STS 51-L, the Challenger. These case studies brought out the ethical, engineering, and economic issues in design of the Solid Rocket Booster, an important component of a space shuttle.

Part IV, Chapter 12 provided the engineering fundamentals behind satellite and web-based telecommunications networks and explained the industry structure of telecommunications industry. Chapter 13 detailed the AUCNET USA case study that shows the decision faced by the management on whether to continue satellite-based automobile auction or switch to a web-based auto auction. It brought out technical, marketing, pricing, security, and network issues.

Part V, Chapter 14 concludes the monograph by pointing out how it was written using an iterative design method and the results of an evaluation performed on the effectiveness of using the materials in engineering classrooms. It concludes by providing excerpts from engineers at Hewlett-Packard Corporation stressing the need for engineers to balance their technical knowledge with business, financial, management, and ethical knowledge.

Lesson Plan

The monograph was used to teach a sophomore-level engineering design course during Fall 1998. The lesson plan for this course follows. In this course offering, we did not use the AUCNET case study due to time constraints.

Week 1	Chapter 1: Overview of Course, Introduction
Week 2	Chapter 2: Decision-Making Theories and Decision Support Software
Week 3	Chapter 3: Introduction to Power Industry
	Chapter 4: Introduction to Maintenance Technologies
	Assignment of Chapter 5: Della Steam Plant Case Study
Week 4	Classroom Discussion of Chapter 5, Instructor Feedback, and Videos
	Assignment of Chapter 6: Crist Power Plant Case Study.
Week 5	Classroom Discussion of Chapter 6, Instructor Feedback, and Videos
	Exam #1
Week 6	Chapter 7: Engineering Ethics
	Chapter 8: Engineering Design Fundamentals
Week 7	Chapter 9: Solid Rocket Booster - A Technical Overview
	Assignment of Chapter 10 and 11: Solid Rocket Booster
Week 8	Classroom Discussion of Chapters 10 and 11
Week 9	Instructor Feedback, Videos
	Chapter 14: Summary and Conclusions
Week 10	Final Exam

Grading (100 points):

Tests on Competency Material Chapters/ Midterm	30
Case Study Discussions	40
Participation, Attendance	10
Final Examination	20

This schedule allowed the instructor to use three case studies during the course. The videos and multimedia materials helped the instructor explain the events that happened at the industry and enhance the feedback given to students.

Administering the Case Studies in Engineering Classrooms:

The lesson plan was used in the mechanical engineering sophomore-level design course (ME 260 - Concepts of Engineering Design) to instruct 23 students. The course consisted of both lectures and case study analysis. During the lectures, the topics in the competency material were discussed. That formed the basis for the discussion of the case studies by student teams during the subsequent week. In order to explain the process of administering the case study, we provide below an example of administering a case study. Due to space constraints, we are not discussing the details of administering the other case studies.

We assigned Della Steam Plant case study during week 3. Each student was given a CD-ROM containing the case study. A written version of the case study and competency materials was available in the monograph. The students were divided into four teams. Two groups assumed the roles of the plant engineer and the original equipment manufacturer (OEM) engineer. Another group assumed the role of the manager and resolved the dilemma faced by him since the two engineering groups recommended two different solutions to the problem. A fourth group discussed how the problem could have been avoided if the plant chose to implement new technologies. During week 3, the students worked individually and in teams to analyze the problem and came up with their own recommendations. During week 4, each team made a presentation in the classroom. Each team provided a written report that documented its recommendation.

Grading of Case Study Analysis

A difficulty in evaluating case study analysis is that it is a team effort and individual contributions of students are not apparent. Therefore, we developed the concept of an electronic journal. The students were asked to maintain a journal and answer the following questions after completing each case study. They were required to e-mail the journal at the end of each week to the instructor.

Every time you work on a case study, complete Part A.

Part A:

1. Date:
2. Goals I intend to complete this work session:
3. The method I used to complete my goals (Explain your thinking as you progressed through the various steps of the case):
4. Self-assessment of your own problem-solving method used and thought processes employed. (Assess # 3.)

Please complete Part B by the end of each case.

Part B For each case, respond to all of the following prompts. You may want to respond to these prompts at various points throughout the case.

1. What questions or comments came to your mind as you progressed through the case study?
2. What surprised, interested, or impressed you about your progress on the case study?
3. What did you learn while you were working on your case study, and how did you feel about it?
4. What did you find most difficult to tackle while you were working on your case study?
5. If you were to give advice or directions to someone new to this case study, what helpful hints would you offer?
6. What aspects of the case study have you enjoyed thus far and why did you enjoy it so much?

7. What information did you learn from you case study that you can predict using in your future career? For your final entry per case, please respond to the following:
8. As a result of the project-based case study you just completed, what have you learned about yourself as a thinker, a planner, a problem solver, and an engineer?

Following each case study session, the instructor evaluated student contributions by reviewing the students' oral and written recommendations and assigning a point score to their contributions. Separately, the instructor also evaluated materials and reviewed the electronic journals submitted by the students. This feedback provided the instructor enough information to evaluate the progress in learning throughout the quarter in order to reward individual performance. The components listed in the lesson plan were followed in order to derive the final grades for each student.

Providing Feedback to Students

The instructor provided the grades to the students a week after the case studies were administered in the classroom. In addition, he discussed the solution adapted by the company to the problem and showed examples of how other student teams had analyzed the case study. For a few of the case studies, the manager who made the decision was present in the classroom during the feedback session. There was lively interaction among the students, faculty members, and industry manager on the pros and cons of the solution adapted by the company. Students were creative in coming up with new and thoughtful solutions to the problem, which were different than the ones adapted by manager.

Evaluation of the Effectiveness of This Course

As part of the evaluation of the effectiveness of the case studies, the students in the Concepts of Engineering Design class responded to two evaluation forms as well as a final evaluation to capture their responses to this class. Following are evaluation results for individual case studies, the student journals, and the overall course evaluation.

Della Steam Plant

The items on the two evaluation forms collapse meaningfully into nine primary constructs. Realizing that a score of 5 on the evaluation forms indicates the most positive response possible, the students in ME 260 responded favorably to each of the case studies. For the Della Steam Plant case study, the median ratings for all but one of the nine constructs equaled or exceeded a score of 3.4. Communication Skills, not a direct objective of an engineering design course, received a rating of 2.5. Otherwise, all were above a neutral 3.0 median rating point. In fact, five constructs (Important and Valuable, Relevant and Useful, Self-Reported Learning, Intrinsic Learning and Motivation, and Learn from Fellow Students) all earned median ratings of 4.0 from the students. The comments from the evaluations also emphasized the favorable reaction of the students to the case study. Specifically, the students felt as though the case study gave them an understanding of real-world situations while also assisting them in the development of cognitive skills, such as decision making.

Crist Power Plant

Similarly, the Crist Power Plant case study received favorable responses from the students. On this particular case study, all nine constructs of the evaluations even

Communication Skills, received median ratings of 3.0 or better. In particular, the students found this case study Relevant and Useful (Median = 4.0) and effective in Learning from Fellow Students (Median = 4.0). Once again, the responses and comments indicated that the students found the case study "informative" and "well-organized." Students appreciated that the case study brought "a practical situation in to train" them as engineers.

Solid Rocket Booster Field Joint

The Field Joint on Solid Rocket Booster case study (SRB case study) also received favorable–in fact the highest–ratings on all nine constructs. All mean ratings for the nine constructs exceeded a 3.5. The constructs of Relevant and Useful (M = 4.32) and Self-Reported Learning (M = 4.23) received the highest mean ratings on the evaluations, with Communication Skills (M = 3.5) receiving the lowest mean ratings. Again, the comments were positive, particularly in the sense that the students remember the Challenger Disaster, which made this case study experience more emotionally charged and personally relevant.

When comparing the mean ratings of the Della Steam Plant case study (the first of the quarter) with the SRB Case Study (the final of the quarter), the absolute mean ratings on all nine constructs for SRB exceeded those of Della. In fact, the mean ratings were significantly higher for the final SRB case study on five of the constructs–Interesting and Exciting, Perceived Skill Development, Intrinsic Learning and Motivation, Instructionally Helpful, and Communication Skills. This finding suggests that, in addition to perceiving the benefit and value of the case studies, the students did not tire of the instructional approach, as they became familiar with the methodology throughout the quarter.

Student Journals

The student journals, which were completed for each case study, demonstrated the use and development of higher order thinking skills–one of the course's primary objectives. Specifically, the students' comments in the journals indicated that they were engaging in sophisticated and complex levels of cognitive activity–defining, analyzing, evaluating, reflecting, and assessing. Not only did the students employ these skills, but also they applied these same skills to assess their own thinking processes and, hence, gain self-insights. The students' comments in the journals also indicated that they were making the necessary connections between the theories they studied and the practice they would assume.

Final Course Evaluations

Final course evaluations consisted of 15 items that asked the students to assess various aspects of the learning experience. All items received favorable mean ratings of 3.5 or above. The highest mean ratings occurred for the item which asked if the students felt they had learned relevant material (M = 4.2) and the item which asked if the students would recommend the course to others (M = 4.3).

Effectiveness of the Course in Achieving Objectives

The case study method of instruction appeared to combine theory with practice as well as encourage the use of higher-order thinking skills within the students – the two primary objectives of this particular class. In the individual cases, the students applied their knowledge of engineering design and management issues in making decisions. They had to analyze alternatives, make a choice, and defend that choice—all-important steps in the critical thinking process. Working in teams, they learned from each other. The data from the various aspects of the full evaluation seem to indicate that the case study method of instruction, which incorporated technology, is a worthwhile and beneficial method of instruction for teaching an engineering design course. Through positive median and mean ratings, the students indicated their favorable responses to each of the three case studies presented during the course.

How This Course Meets the Objectives of ABET 2000 Criteria

The design, administration, and evaluation of the course shows that it meets some of the ABET 2000 criteria. The evaluation results from this course were analyzed to identify how it met the ABET 2000 criteria.

(a) An ability to apply knowledge of mathematics, science, and engineering: The course achieved this objective by providing an opportunity for the students to apply principles of engineering learned in earlier courses to solving real-world problems. The student comments indicated that this criterion was achieved to a limited extent:

> I learned that Southern Co. was the largest producer of electricity in the U.S., the relationship between 1x and 2x vibrations, the basics of how a steam turbine-generator operates mechanically, and how the Expert Choice Decision Support System works and its benefits in the workplace. I found this information to be very intriguing.

(b) An ability to design and conduct experiments, as well as to analyze and interpret data: Although the students did not design an experiment, they were exposed to data collected by practicing engineers on the vibration of turbines and failure of O-ring in field studies. The students had to understand and analyze these data to come to conclusions. The student comments indicate that this criterion was achieved to a limited extent:

> 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 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.

(c) An ability to design a system, component, or process to meet desired needs: The students' learn about how professionals design a system (such as the Solid Rocket Booster or a satellite auction system) in response to market needs. The case studies provided opportunities to critique the design and learn from the past to a limited extent:

> 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.
>
> I learned that in most case there is never a definitive 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.

(d) An ability to function on multi-disciplinary teams: The students had to work in teams in order to find answers to the problems. The classroom administration was constrained to teams from the same discipline. The student comments indicate that this criterion was achieved to a limited extent:

> The team discussion was both productive and 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. Interdisciplinary approach is the strength of the case study.

We use multi-disciplinary teams in order to create the instructional materials and case studies. These teams are composed of undergraduate, graduate, and doctoral students from engineering and business. The student workers' comments indicate that this criteria was achieved to a large extent:

> Working on a multi-disciplinary team of professors and students to produce project deliverables was a very rewarding experience because it helped to improve communication and team skills. I am confident that this experience will be beneficial to my career after college.
>
> I found myself not only learning more about certain areas/specialties in engineering, but also in areas of business and government. When integrating several aspects/areas of study to form a cohesive yet dynamic piece of work, it is very natural to get carried away by the influx of information. So it was as a much a learning process for me to deal with great amounts of information, and discern what is relevant and necessary, as opposed to what is just interesting.

(e) An ability to identify, formulate, and solve engineering problems: This was the major task expected of each student team after analyzing the case studies. The evaluation results show that this was achieved extremely well in this course. The student comments indicate that this criterion was achieved to a great extent:

> I noticed that this one case actually helped me analyze my thought processes. I feel that my problem-solving methods have become keener. 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.

(f) An understanding of professional and ethical responsibility: We had introduced a case study that discussed ethical responsibility of engineers and provided them competency material on this topic. The student comments indicate that this criterion was achieved to a good extent:

> 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.
>
> 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 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.

(g) An ability to communicate effectively: The written reports and oral presentations provided opportunities for students to work on their communication skills. The evaluation results show that this criterion was achieved to a good extent during the course:

> 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.
>
> Knowing that this case study was an actual problem faced by real engineers in a power plant gave the assignment a refreshing feel. There was no inherently right or wrong answer. Rather, the students were forced to think on many levels, to analyze the problem using many criteria, not just a couple of formulas or a few pages of calculations. We were challenged to develop our rusty skills of communication and collaboration in order to achieve the best result.

(h) The broad education necessary to understand the impact of engineering solutions in a global and societal context: The case studies provided an opportunity for the students to understand the impact of the solutions for the company. Their comments show that this criterion was met to a limited extent. They commented on the use of Expert Choice software as a decision-making aid in the Crist Power Plant case study:

> I think computer-based decision making is going to be a big hit in the engineering world, and I think that is going to be the biggest information that I already know because of this case study. The computer based decision software helps you put your information into perspective instead of just making a choice.

(i) A recognition of the need for, and an ability to engage in, life-long learning: Many students recalled the case studies even after couple of quarters. One of the students who is now an alumni of Auburn University recognized the value of the course and strongly recommended to his management that a case study needs to be developed for their plant. Based on this feedback, we are developing a case study that shows the problems in making a cooling tower more efficient in a nuclear power plant.

(j) A knowledge of contemporary issues: The case studies deal with issues that are relevant to current engineering students such as predictive maintenance, Decision Support Systems, lessons learned from failure of engineering design, and web-based auto auction systems. The students' comments show that this criterion was met to a limited extent:

> The CD-ROM facilitated my understanding of the case study immensely. The use of the different multimedia grabbed my attention and allowed for greater information retention.
>
> I enjoyed looking at all the information on the CD-ROM because it had pictures and graphs and explained the problems and sides of the story. I enjoyed hearing the two sides of the story and the problems that each one incurs with each.

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: The case studies stress the ability to use past knowledge in order to solve practical problems encountered in engineering practice. Student comments indicate that this criterion was met to a great extent:

> 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.
>
> 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 learned more about turbines in this case study than I did on a tour to a steam plant years back.

As shown above, this methodology strongly met criteria (b), (d), (e), (f), (g), (h), and (k). It is very difficult to meet these criteria using a traditionally taught design course. This shows that this course not only met the objectives we set forth, but also strongly some of the ABET 2000 criteria. This teaching methodology received the 1999 Curriculum Innovation Award from the American Society for Mechanical Engineers (ASME).

Summary and Conclusions

The design course for sophomore level students was taught using the innovative teaching methodology described in this paper for the first-time during Fall 1998. The evaluation results show that the course appeared to fulfill the primary objectives of this class by combining theory and design with practice as well as encouraging the use of higher-order thinking skills within the students. The use of real case studies developed in partnership with industries brought real-world problem solving scenarios into the classroom. The case study approach used in this methodology provided opportunities for students to work in teams, learn from peers, and learn from themselves. Also, the students had opportunity to engage in sophisticated and complex levels of cognitive activity–define, analyze, evaluate, reflect, assess, and solve real-world problems. The evaluation suggests that implementation of this methodology in this engineering design course improved the higher-level cognitive skills of the students as well as integrated theory, design, and practice.

This course administered based on these materials has proven to fulfill many of the criteria specified by ABET 2000. We believe that widespread implementation of this type of curriculum across engineering campuses has the ability to better prepare engineering students for real-world problem solving situations and retain their interest in engineering subjects. In order to provide faculty members access to the innovative methodology and instructional materials, Raju and Sankar are developing a textbook to be published by Prentice Hall Publishers.

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Dr. Chetan S. Sankar is a Professor of Management at Auburn University specializing in telecommunications and Management Information Systems. He won the 1995 Decision Sciences Institute Instructional Innovation Award for its outstanding contribution to the Decision Sciences and selected as the outstanding researcher in the College of Business during 1997. Dr. Raju and he are the editors-in-chief of the Journal of SMET Education: Innovations and Research.

Dr. Gerald Halpin is a Professor of Educational Research and Statistics at Auburn University. He has directed or co-directed a number of research projects which has been funded from a variety of local, state, and national agencies with support totaling over $1.5 million. Among his current projects is the evaluation of a $5

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