AC 2010-1369: USE OF MULTIMEDIA CASE STUDIES IN AN INTRODUCTORY COURSE IN MECHANICAL ENGINEERING

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Use of Multimedia Case Studies in an Introductory Course in Mechanical Engineering

Abstract

Many of the core concepts in engineering are complex andprecise. Hence, university students taking introductory classes in engineering, even those with high entry qualifications, often have difficulty learning these concepts and applying them to problem-solving tasks. This problem is more pronounced when the class size is large[1]. The National Academy of Engineering[2] recommends that universities should address how students learn in addition to what they learn in order to ensure that student learning outcomes focus on the performance characteristics needed in future engineers. This paper addresses how case study–based instructional strategy has been used as an effective tool in an Introductory Course in Mechanical Engineering (ENGR 1110) at the freshman level to overcome these problems. This instructional strategy has been in use during the past three semesters at Auburn University, and the evaluation results show that the students involved obtained a thorough understanding of the engineering concepts and also improved their soft skills, including team working, communication, and ethical and problem solving skills. In-depth information about the evaluation results, course map and instructional strategy are provided in this paper.

Introduction

Engineering curricula have experimented with multiple methodologies that expose students to real-world problems. There are also deep concerns about American international competitiveness, amid indications that the U.S. is doing a relatively poor job at retaining and training students in the science, technology, engineering, and mathematics (STEM) disciplines[14]. Too many talented students get the impression from introductory courses that engineering is simply a collection of facts to be memorized and consequently drop out with little understanding or appreciation of what science is all about[3]. Furthermore, the types of problems students often solve in classrooms using the traditional teaching approach do not necessarily prepare them for the real-world problems they will encounter as engineers. Real-world problems are complex and ill-structured, often have conflicting goals and no clear solution, and can be presented in a number of ways [4]. Yadav et al.[13] found that there was no significant difference between traditional lecture and case teaching method on improving students' conceptual understanding of engineering subjects. However, the use of case studies made the content more relevant to the students by informing them about what engineers do

So in order to give students an opportunity to receive this much-needed exposure to real-world problems, an instructional strategy was developed. This strategy used real-world case studies developed by the Laboratory for Innovative Technology and Engineering Education (LITEE) at Auburn University. This paper discusses how these case studies have been used to (a) develop specific student capabilities and (b) help students learn certain engineering principles and apply them to solve problems occurring in real-world situations.

Case Study:

A case study typically is a record of a technical and/or business issue that has actually been faced by managers together with surrounding facts, opinions, and prejudices upon which management decisions must 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.[5], are:

1. *The primary 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' focuses have 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[6.]

Case studies have traditionally been used to show how real-world decisions need to be made so that financial goals, technical needs, safety factors and credibility issues are simultaneously considered and weighed[7,8.] During the past fourteen years, the Laboratory for Innovative Technology and Engineering Education (LITEE) at Auburn University has been producing case studies in engineering, business and technology areas and has been successfully implementing them at Auburn and several other universities with a very high percent of positive feedback on them.

The LITEE case studies are developed by graduate students working with professors and industry personnel. These teams identify a suitable problem and bring it alive in the classroom through a multimedia case study, ensuring that students explicitly see the connections between theory they've learned in the classroom and its practical applications. A summary of the Case Studies used in an Introduction to Engineering course are listed below. These case studies are available for free use from the website www.liteecases.com.

STS 51-L Case Study

This case study shows the events leading up to the decision to launch the space shuttle STS 51-L (Challenger). The case also describes the events and illustrates the technical details discussed in the study.

Learning Objectives:
- To evaluate alternative design options using ethical, safety, reliability, risk, schedule, and cost factors; students must choose an option and defend it.
- To apply principles of ethics stated in codes of professional societies to an engineering decision-making scenario.

Key Features:
- Provides background materials on ethics and design so that the students can analyze the case study effectively.
- Includes topics relating to ethics, design of O-rings, project management, risk, and safety.
- Satisfies the ABET 2000 criteria for developing the students' abilities to use techniques, skills, and modern engineering tools necessary for engineering practice.
- Perfect for a freshman course conveying the design and ethical challenges that engineers face, but also suitable to teach details of design at a sophomore level or higher.
- A timeline in the CD-ROM takes the reader through design decisions and challenges faced by NASA engineers from 1972 to 1986.

Della Case Study

The case study illustrates a turbine-generator unit in a power plant vibrating heavily and shaking the building. Two engineers recommend conflicting solutions. Sam Towers, the plant manager, has to make a decision that could cost the company millions of dollars.

Learning Objectives:
- To integrate engineering and business issues by understanding that good decisions require striking a balance between technical, financial, credibility, and management issues
- To synthesize and apply knowledge gained in earlier courses to solve a real-world problem.
- To gain higher-level cognitive skills such as reasoning, critical thinking and problem solving skills.

Key Features:
- Highlights the need for engineers to interpret engineering data, analyze financial implications, and make recommendations to the management.
- Covers engineering issues, risk management, safety, credibility issues, and financial issues.
- Satisfies ABET 2000 criteria for developing the student's ability to use techniques, skills, and modern engineering tools necessary for engineering practice.
- Graphically illustrates the problem using photos, videos, and charts.
- Competency materials provide technical and management information needed to solve the problem.

Lorn Case Study

This case study highlights the importance of safety and serviceability considerations in the design of a lap-winder machine used in a textile mill. It describes how a worker in a textile mill lost three fingers while performing maintenance on this machine and follows the ensuing court case.

Learning Objectives:
- To teach students how to use basic skills needed by professional engineers, including technical accuracy, an understanding of the codes of standards, ethical design, and communication.
- To give students a better idea of the role expert witnesses play in contemporary engineering problems.
- To emphasize the importance of safety in design, including lock-out/tag-out procedures, limit switches, and safety in theory and in practice.

Key Features:
- Gives students knowledge on how professional engineers would and should apply codes and standards when faced with real world problems.
- Gives an analysis of many other basic skills engineers should utilize, such as safety awareness and communication.
- Shows students the role an expert witness plays in today's legal system and the skills necessary to prove their point to a judge, jury, or board of directors.
- Gives a firsthand account of engineers playing a role in our legal system.
- Shows how to communicate highly technical issues in an understandable manner.

Mauritius Auditorium Design Case Study

This case study focuses on an acoustical design issue that affected the polyvalent hall at the Swami Vivekananda International Convention Center on the island of Mauritius. Background information is provided about companies, architects, and acoustic consultants involved, as well as documents that describe the design problem and the alternative solutions proposed. Students must evaluate four alternative solutions and determine which best resolves the acoustics problem after full review of the courseware.

Learning Objectives:
- To understand problem-solving given global engineering considerations.
- To expose students to acoustical design and acoustics engineering.
- To improve decision making given multiple alternatives to solve a design problem.

Key Features:
- Interactive reverberation simulator to demonstrate design and material effects on the reverberation time of a small room.
- Video interviews with company managers and engineers explaining the problem, alternatives, design issues, and business ethics that must be considered in global engineering endeavors.

- Interactive sound simulator for learning about the effects of reverberation time on the use of the hall for different events such as conferences, rock concerts, and automobile shows.
- Interactive decision support system (DSS) for use in evaluating design alternative.

Course Map for the Introduction to Engineering course with Mechanical Engineering Focus

Figure 1 shows a course map that was developed for the Introduction to Engineering course with an emphasis on mechanical engineering fundamentals. The engineering content materials typically emphasized in this course are: mechanics, principles of electrical power, engineering design, project management, fluid mechanics and acoustics, codes and standards, and industrial safety. Figure 1 shows how these engineering contents will be covered using four LITEE case studies, namely the Della Steam Plant, Challenger STS 51-L, Mauritius Auditorium Design and Lorn case studies. The course map also shows how the course will develop the capabilities required by the engineering profession and ABET. The use of this instructional strategy is expected to lead to the development of the over-arching capabilities shown in the figure, such as recognition of the need for life-long learning, the ability to define and solve problems, and understanding the impact of engineering solutions in a global and societal context.

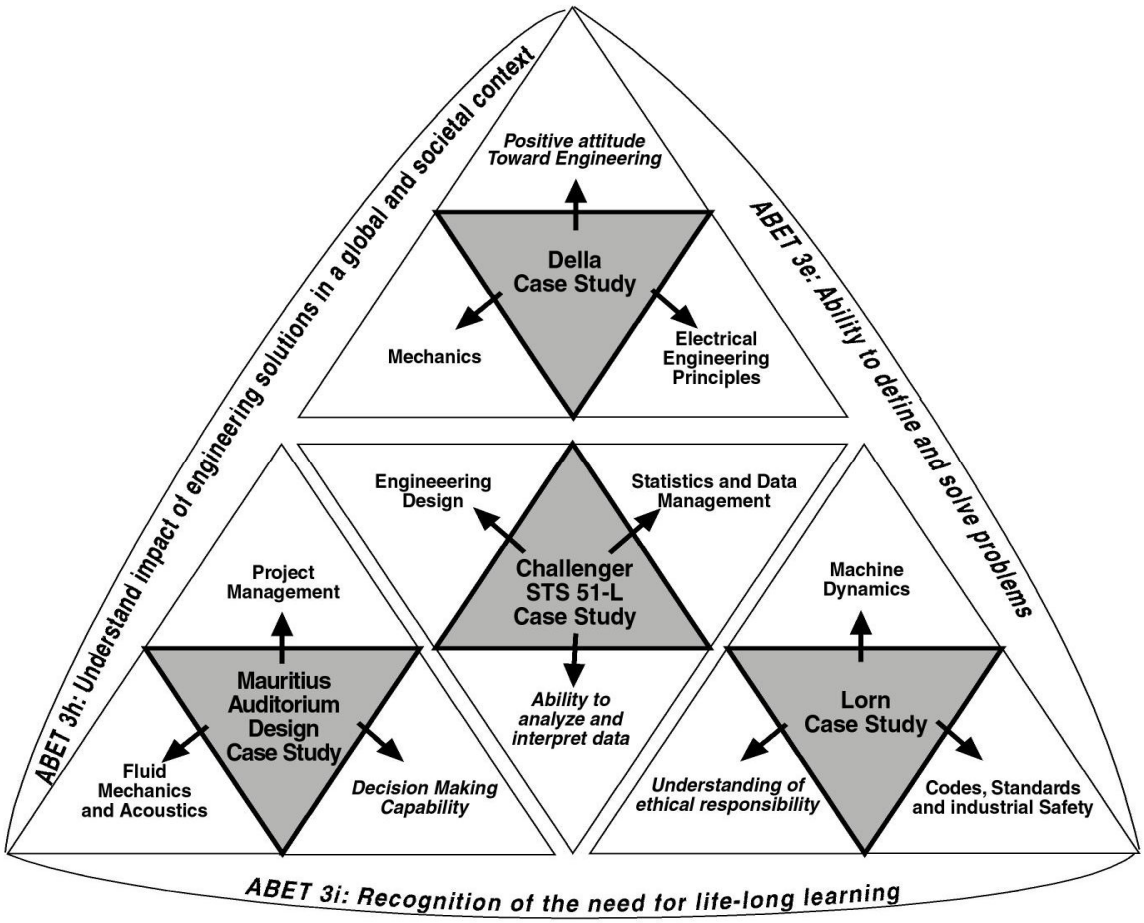

Figure 1: Course Map for Introduction to Engineering course: Mechanical Engineering Emphasis

For example, the Lorn case study provides an analysis of an actual accident that occurred in 1991. A textile mill worker lost three of the fingers on his left hand during a routine maintenance procedure when the Lap Winder that he was maintaining suddenly started up. He sued for negligence in the design and manufacture of the Lap Winder. Two expert witnesses provided testimony for both the defendant and plaintiff. The case study CD-ROM makes available the depositions of the plaintiff, defendant, witnesses, and the expert witnesses. An instructor can provide lectures on the engineering profession and its responsibilities to society, as well as the importance of codes and standards in the design of machinery. The students can use the lecture materials to analyze the case study and come up with recommendations, helping them to understand the concept of ethical responsibility and the importance of being able to communicate effectively.

Instructional Strategy:

An instructional strategy is a set of learning activities in a particular sequence, not just an individual activity or teaching technique that can be plugged in more or less anywhere. This is an important distinction, because a strategy is always more effective than an individual activity. A strategy uses a set of activities that work together synergistically to create a high level of energy on the part of the students that can then be applied to the task of learning[9]. The overall focus of the strategy used in this course is on students' ability to apply what they know as they perform professional tasks, rather than merely accumulating knowledge.

Proposed Instructional Strategy:

Based on a literature review and extensive experience in the classroom, we designed a case study–based instructional strategy to (a) develop specific capabilities in students, (b) help students learn the underlying content of a particular course and apply it to real-world situations, and (c) provide opportunities for students to use the latest information technologies in mastering the subject matter covered in the course.

Although the particular sequence of activities can be and is expected to be modified to fit particular teaching circumstances, the following is a description of learning outcomes for the Lorn case study used in this Introduction to Engineering course. The whole course is restructured by dividing the semester up into four to five case study units focused on the major topics covered in the course. This results in covering several case studies that are each two to three weeks long. For each case study, the instructor then sets up a three-phase sequence: preparation, application, and assessment (Figure 2).

In the *preparation phase*, the instructor provides a pre-test of the concepts that will be covered in this segment, along with a questionnaire that evaluates the expected learning of students using this teaching strategy. Then, the instructor lectures on the concepts that will be covered during this segment. At the end of the lecture, he/she shows segments from the case study CD-ROM and explains the problem. These lectures could be conducted in lecture theaters, but frequently, the instructor will conduct these lectures in the team stations lab since it offers opportunities to break up the lecture and include think-pair-share assignments. In such an assignment, the instructor asks a question or poses a problem. Students spend a minute or two

thinking about an answer or solution. Students then pair up to discuss (share) their answers and use the team-stations to search for answers from the Internet.

The instructor may then ask several students to share their answers with the whole class. At the end of the lectures, a homework task is assigned to ensure that students read the textual material and obtain a good introduction to the information and ideas on this topic. By the end of the preparation phase, students typically have a moderate level of understanding of the material and are thereby ready to start the application phase.

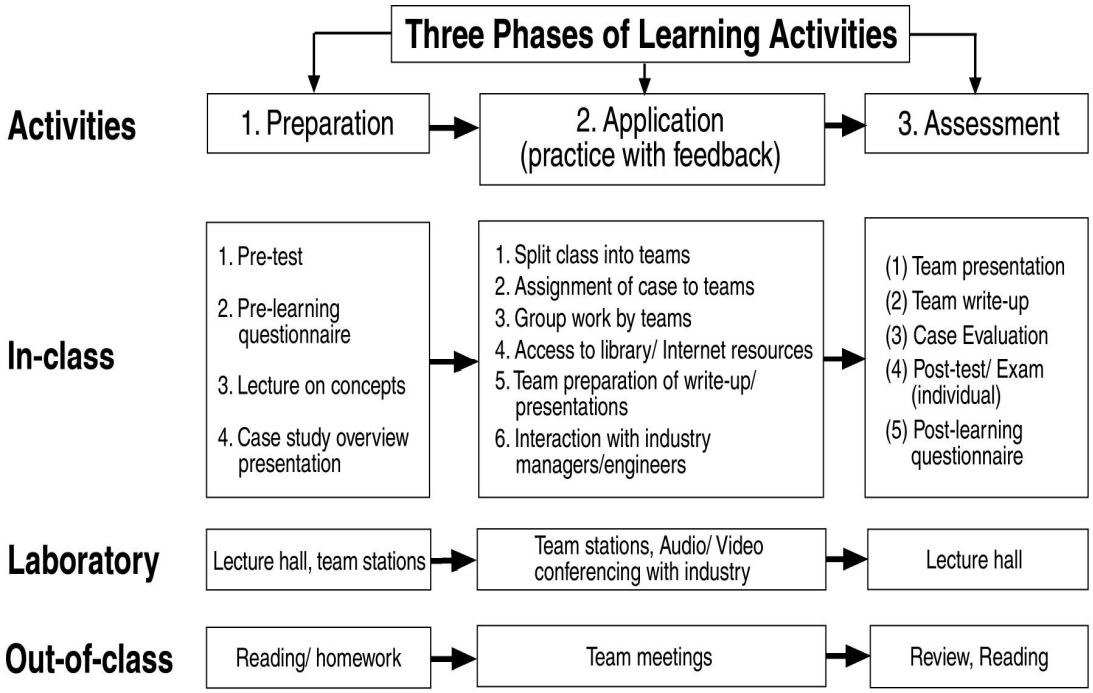

Figure 2: The sequence of learning activities for one case study covering a 3 week block of time

In the *application phase*, the instructor divides the students into teams and assigns the case study. Typically, the assignment involves each team assuming the role of a specific engineer/manager who comes up with recommendations to the problem, consultants who provide solutions, and the final decision maker. Students spend class time in analyzing the case study, working in teams using the team-stations, sharing work with each other, and preparing their presentations. The instructor is available in order to assist the students during the application phase. If available, students can also talk with the engineers/managers in the related industry using class interaction or audio/video conferencing in order to obtain further clarifications about the problem and potential solutions. Students frequently meet by themselves in out-of-class sessions in order to further prepare for the presentations. At the end of this phase, the students make their presentations.

During this phase, the instructor can use many of the tools available to promote active learning. "If you want students to learn thinking, reasoning, problem solving, and decision-making skills, then it's essential to use cooperative and collaborative learning," says Davidson[10]. By actively engaging in the learning process, students very quickly assimilate new concepts, understandings, and skills that they don't develop just by sitting through the lecture. Combining segments of lecture with short active learning activities is an excellent way to keep students interested and involved. Naturally, improved levels of interest and attention increase learning. Thus, giving a few minutes of lecture time for an active learning activity can actually increase the amount of information covered and retained, rather than decrease it[6]. A number of activities that have been successful in the Introduction to Engineering classes are given below. The instructor can choose appropriate methods from this list:

(a) Planning: be prepared, make the task clear to students (prepare the assignment in written form). Make sure the task is clear, specific, and discrete.
(b) Ensuring participation: make learning objectives clear and require a group product. Students will not view an activity as "busy work" if the objectives of that activity are made clear to them[8].
(c) Maintaining order: limits on time and group size. In a large class, it is usually best to keep group work fairly simple and the time frame short. Time periods from two to ten minutes for group activities, interspersed with segments of the lecture are used.
(d) Participatory lecture: Students shout out suggestions or answers to questions. This initiates a jointly created coherent understanding of the topic[12].
(e) Think-pair-share: The instructor asks a question or poses a problem. Students spend a minute or two thinking about an answer or solution and then pair up to discuss (share) their answers. The instructor may ask for several students to share their answers with the whole class.
(f) Student demonstrations: Student demonstrations can be a quick way to make a point more vivid, give students a chance to hear from their peers, and give everyone in the class a "think break."

In the *assessment phase*, each team makes a presentation defending the recommendation of the engineer/manager they were assigned to play. The presentations are normally restricted to 10 to 15 minutes so that the students are required to present their view point succinctly. Sometimes, they also provide a write-up summarizing their recommendations. The instructor provides an evaluation of the case study presentation, a write-up on the strengths and weaknesses of the team, and points for their presentation. In addition, tests/exams are often developed by the instructor to test the students' mastery of the concepts and case study materials. Administering these tests/exams provides the instructor with an assessment of the student learning of the concepts and contents covered in the course. Students grasp many of the concepts by the end of this phase.

Learning Outcomes

In Table 1 below, we illustrate examples of expected learning outcomes from the use of the Lorn Case study in this course, along with the content areas of machine dynamics, codes, standards, and industrial safety and ethical responsibility outcomes.

Cognitive Domain	Learning Outcome Example
Knowledge	Give a broad definition of engineering term; ANSI standards, expert witness
Comprehension	Explain physically how a lock out/tag out procedure is used in a textile plant
Application	Apply the ANSI standard L1.1, 1981 to the problem
Analysis	Discuss whether the lap winder machine met the ANSI standard
Synthesis	Understand how a legal issues such as contributory negligence needs to be considered in designing a safe machine
Evaluation	Come up with alternate solutions to make the machine operationally safe
Affective Domain	**Learning Outcome example**
Receiving	Show interest in a lecture on industrial safety
Responding	Participate in class discussion
Valuing commitment	Assume responsibility for participating as expert witnesses and lawyers during mock trial assignment
Organizing a value system	Show passion in arguing for industrial safety procedures
Characterization-philosophy	Develop an interest in engineering and its importance to society

Table 1: Example Learning Outcomes for Lorn Case Study and Associated Content

Evaluation Results

The LITEE case studies have been used in engineering courses at Auburn University for several years and at Hampton University during a semester. So far, we have implemented questionnaires to gauge students' perceptions regarding the use of these case studies. In addition, the teachers were asked to comment on their observations of student learning. This section discusses the results of this study.

An experimental and control section were used at Auburn University to obtain students' perceptions on the capabilities they achieved during an Introduction to Engineering course during spring 2006. This four-hour-per-week course, conducted by two senior faculty members in the College of Engineering, consisted of a one-hour lecture class and a three-hour lab session each week. The capabilities to be achieved by students enrolling in the experimental and control groups were to work effectively in teams, communicate engineering concepts succinctly and clearly, improve engineering design skills, use safety and standards concerns in engineering design, be aware of business issues in designing products and systems, and integrate math and science principles in solving engineering problems. In both sections, lectures and a design

project were used. In addition, in the experimental section, three case studies, Della Steam Plant, Challenger STS 51-L, and Lorn Manufacturing, were used. A summary of these case studies is given in the Experimental Design section above. Lab sessions were organized so that, with about 20 students in each lab, students were divided into teams and provided specific assignments. Each case was analyzed during two class periods. During the third class period, each team made a presentation defending the roles they had been assigned using the technical and business information provided in the case study. The control sections spent their lab time working on mini projects.

A similar experimental and control section design was used at Hampton University during fall 2008 to teach an introduction to engineering course. The course objectives for both sections were that, after taking the course, students should be able to do the following: define the engineering profession and various engineering disciplines; cite reasons why they have decided to become engineers; identify and formulate engineering problems; solve problems on engineering systems applying physics, mathematics, energy and basic engineering methods; apply various mathematical methods for the solution of engineering problems; write engineering reports on projects; make an oral presentation on an engineering project; collect information and data in the library and World Wide Web and compose an article using the collected information; apply the basic engineering design methodology; apply basic concepts of statistics related to engineering problems; and use ethical, societal, environmental and safety considerations to make engineering design decisions. In both sections, lectures were used to teach these concepts. In addition, three case studies were used in the experimental section. Four class periods were set aside for presenting and discussing case studies.

The assessment of student learning in both institutions was conducted through the use of a questionnaire that measured the students' perceptions on achieving higher-order cognitive skills, improvement in self-efficacy, and improvement in team working skills[11]. These questionnaires were completed by the students in the experimental and control sections at the start and end of the course. The items in the questionnaire were combined to compute the means and standard deviation of the measures. Table 2 shows the results that were computed for the experimental and control sections at both Auburn and Hampton Universities.

The students in the experimental section at Auburn University perceived that their higher-order cognitive skills had improved significantly, whereas the students in the control section perceived a small drop, although this was not statistically significant. The students' perceived self-efficacy improved significantly for the experimental section, whereas it decreased significantly for the control section. The students in the experimental section perceived that their team-working skills had improved significantly, whereas once again the students in the control section reported a significant drop.

At Hampton University, students in both the experimental and control sections perceived their higher-order cognitive skills at the end of the course to be lower than the levels anticipated at the beginning. However, while the drop was not statistically significant for the experimental section, the fall off was highly significant for the control section. On both the self-efficacy and team working dimensions, students in the experimental section perceived they had improved, although the mean increases were not statistically significant. In comparison, students in the

control section perceived a significant decrease in self-efficacy and a substantial (though not statistically significant) decrease in team working skills.

Comments made by the instructor and students in the experimental section at Auburn University included the following:

- The case studies show the students that engineering requires judgment despite limited knowledge, conflicting information, and uncertainty. They show that the livelihoods, even the lives, of people are daily engineering responsibilities. These case studies reveal the importance of ethics and professionalism in engineering. The students see that engineering is not only a technical career but has a very high "human" component.
- Seven out of eight African-American students in the class preferred an interactive learning environment. The students indicated that the case studies were a very positive experience in their learning of engineering principles. They found the case studies to be informative, interesting, and enjoyable.
- Students commented that the case studies were fun, allowed them to explore new material, and provided them the opportunity to apply the engineering, analytical, and technological principles they learned in class to problems that they may encounter in their future work.

Table 2: Results of Perceptual Measures

Goals	**Experimental Section, Auburn University, n=51**		**Control Section, Auburn University n = 75**		**Experimental Section, Hampton University, n=18**		**Control Section, Hampton University, n=23**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1. Gain in Higher-order cognitive skills	3.5 (0.6)	3.7** (0.7)	3.5 (0.6)	3.4 (0.7)	3.7 (0.9)	3.4 (0.8)	3.7 (1)	3.0 (.8)***
2. Improvement in self-efficacy	3.2 (0.4)	3.4** (0.5)	3.2 (0.6)	3.1** (0.6)	3.5 (0.6)	3.7 (0.8)	3.6 (0.8)	3.1 (0.8)**
3. Improvement in team working skills	3.4 (0.6)	3.7** (0.8)	3.7 (0.5)	3.5** (0.8)	3.3 (0.5)	3.6 (0.9)	3.5 (1)	3.1 (0.9)

- Scale: 1 – Strongly disagree; 3 – Neither agree nor disagree; 5 – Strongly agree
- *** - difference between pre and post means significant at 0.01 level;
- ** - difference between pre and post means significant at 0.05 level

The instructors in the experimental sections observed that the students' interest in engineering subject matter, self-efficacy and team-working skills improved. They also observed

that students with different learning styles and behavioral tendencies seem to relate to the case studies effectively and were able to complement each other's personalities when working as members of a team. Although the instructors observed that female and African-American students responded to this instructional methodology favorably, a rigorous research design was not used to measure the significance of race or gender.

Conclusions:

The study was based only on perceptions measured using a questionnaire and was not based on a theoretically derived research model. Given the importance of this topic as shown in the introduction section, we have recently obtained a grant from the NSF that develops and tests a research model that investigates the moderating effect of instructional methodologies on the relationship between the presage factors (gender, learning styles, behavioral tendencies, and race) and improvement in achieving learning outcomes. The moderating effect has the ability to increase and decrease the improvement in achieving learning outcomes and might be compared to the function of a dimmer switch, which can increase or decrease the brightness in a light. We plan to report the results of this research in future conferences and journal papers.

The case study based instructional strategy is an interesting option for engaging students and presenting complex material. Students, teachers, managers, and engineers from industry view cases as effective tools for instruction. Case studies also allow us to introduce problems and questions we could not otherwise consider, and they have the potential for students to achieve higher-order cognitive skills.

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References:

1. Nichol, D.J. and Boyle, J.T. (2003). "Peer Instruction Versus Class-wide Discussion in Large Classes: A Comparison of Two Interaction Methods in the Wired Classroom," Studies in Higher Education: 28(4): 457-473.
2. National Academy of Engineering (2004). Educating the Engineer of 2020, Washington, DC.
3. Seymour, E., and N.M. Hewitt. 1997. *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder, CO: Westview Press.
4. Jonnasen, D., J. Strobel, and C.B. Lee. 2006. Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education* 95
5. Barnes, L.B., C.R. Christensen, and A.J. Hansen, Teaching and the Case Method: Text, Cases, and Readings. 1994: Harvard Business School Press.
6. Carbone, E.L. (1998). Teaching Large Classes : Tools and Strategies, Sage Publications, Thousand Oaks, CA.
7. Shaha, S.H., Integrated outcomes: where CIOs need to be thinking. Health Management Technology, 1998. 19(10): p. 44-6.
8. Small, C.R. (2005). "The Implementation and Evaluation of OASIS: A Web-Based Learning and Assessment Tool for Large Classes," *IEEE Transactions on Education*, 48(4): 658-663.
9. Hargrove, S.K. and Dahleh, M. (2006). Using Multi-Media Courseware to Enhance Active Student Learning in the Classrooms, 2006 ASEE Conference, Chicago, IL.
10. Davidson, N., quoted in Carbone, E. (1998). *Teaching Large Classes*, Sage Publications, Thousand Oaks, CA.
11. Raju, P.K. and C.S. Sankar, Teaching Real-World Issues through Case Studies. Journal Of Engineering Education-Washington-, 1999. 88: p. 501-508.
12. Frederick, P.J. (1987). Student involvement: Active learning in large classes, in M. Weimer (Ed.), New directions for teaching and learning: Teaching large classes well (pp. 45-56). San Francisco: Jossey-Bass.
13. Aman Yadav, Gregory M. Shaver, and Peter Meckl (2010). " Lessons Learned: Implementing the Case Teaching Method in a Mechanical Engineering Course" Journal of Engineering Education".
14.William B.Wood (2009). "Innovations in teaching Undergraduate biology and why we need them", Annual review of cell and developmental biology.15. ABET, (2007). http://www.abet.org/forms.shtml, Retrieved April 12, 2007.
16. Balamuralikrishna, R. and Rosentrater, K. (2006). An Evaluation of an Established Case Study for Engineering Technology Education, 2006 ASEE Conference, Chicago, IL.
17. Chinowsy, P.F. and Robinson, J. (1997). "Enhancing Civil Engineering Education through Case Studies," Journal of Engineering Education, 86(1): 45-49.
18.Davidson, N., quoted in Carbone, E. (1998). Teaching Large Classes, Sage Publications, Thousand Oaks, CA.
19. Larry G. Richards, Michael E. Gorman (2004) Using Case Studies to Teach Engineering Design and Ethics 2004, ASEE Conference.
20.Michaelsen, L.K., Knight, A.B., and Find, L.D. (2002). Team Based Learning: A Transformative Use of Small Groups, Praeger, Westport, CT.
21. Mustoe, L.R., and Croft, A.C. (1999). "Motivating Engineering Students by Using Modern Case Studies," European Journal of Engineering Education, 15(6): 469-476.
22. Passino, K.M. (1998). "Teaching Professional and Ethical Aspects of Electrical Engineering to a Large Class," IEEE Transaction on Education, 41(4): 273-278.

23. Vazsonyi, A., Which door has the Cadillac. Decision Line, 1999. 30(1): p. 17-19.