Abstract - Innovative approaches to engineering education are required in order to improve student learning and to graduate students capable of meeting the challenges of the future. One such approach has been implemented at Auburn University, and the students have been tracked longitudinally to study the impact of this innovative instruction wherein theory and practice were brought together. Multimedia case studies were developed and used as a primary instructional mode in experimental classes over a 2-year period. Students in the experimental classes were matched with a comparison group randomly selected from the engineering student population but stratified by high school grades, ACT/SAT, and engineering major. The longitudinal evaluation revealed significant differences in college grade point averages among the groups with the experimental mechanical engineering majors tending to have the best grades. Even more supportive of the experimental program was that a significantly greater proportion of the participants was admitted to study in a professional engineering program from pre-engineering than was found with the comparison participants. These results suggest that the experimental instructional approach employed for the engineering students in this study is indeed an innovation that leads to improved student learning and advancement in engineering.

Index Terms - Case studies, Case-based instruction, Multimedia case studies, Real-world problems

INTRODUCTION

Engineers of tomorrow must be able to effect solutions to global problems. In order to do so, they need to develop skills that are of maximum value to employers [3]. However, as employers have lamented, new engineering graduates do not always have these skills [7]. Although there is not yet a consumer-supplier relationship between industry and higher education [9], the needs of the various constituencies and the expected accomplishments of the graduates must be important considerations in any engineering education program [1].

The Board of Engineering Education advocates that programs of study in engineering prepare their graduates to meet the demands of industry, government, and society [2]. The National Science Foundation concurs, noting that engineering education should be attuned to the needs of industrial consumers [5]. Prados [6], recognizing that the work environment wherein engineers practice is changing dramatically, averred that the needed skills are not likely to be acquired with traditional lecture-based instruction. He advocated engineering courses wherein theory and practice are integrated. Holt [4] agreed, saying that traditional teaching methods have been found to be more expensive and less effective than more innovative approaches.

In response to recognized needs and with support from the National Science Foundation, we established at Auburn University the Laboratory for Innovative Technology and Engineering Education (LITEE) wherein interdisciplinary teams worked to create innovative instructional materials for use in engineering classrooms. Working in partnerships with industries, the teams developed multimedia case studies focusing on real-world problems and solutions. These innovative materials [8] have been used as the primary instructional mode in experimental engineering classes over a 2-year period. Reported herein are results of evaluations conducted within the experimental classes as well as between experimental classes and comparison classes, which serve to validate the multimedia case study approach to engineering education.

EXPERIMENTAL CLASSES

Pre-engineering students are required to take Introduction to Engineering, a freshman-level course that provides an introduction to engineering design, engineering teams, graphical presentation, technical writing, and oral presentation. Traditionally, this course is taught by a variety of instructors throughout the College of Engineering using a lecture-discussion approach. The experimental sections of this course were taught by a mechanical engineering professor using three of the multimedia case studies: AUCNET, Della Steam Plant, and Solid Rocket Booster [8].

Case Overview

AUCNET, AUCNET USA was auction house selling used automobiles. The buyers, however, were in their offices across the country, and the automobiles were still on the sellers’ lots. The auctioneer was in a suburban office building in Atlanta,
Georgia. In the Network Control Center Yuki Oana, CEO of AUCNET USA, was pleased that the company was selling many vehicles using digital satellite technologies to operate the real-time on-line auctions.

He and others in top management were not sure how long AUCNET USA would remain competitive. They were considering changes in network design to include low-orbiting satellites or even the Internet. What could they do to be a technology and market leader? They even wanted to know about other business opportunities the company might pursue.

Student assignments with this case include having a group research and discuss marketing challenges and ways to keep the company successful. Other groups (a) describe information technologies used in the past, (b) discuss issues in modifying technologies used by the Japanese parent company, and (c) suggest new technologies that could be used by AUCNET USA. The task for yet another group is to make recommendations related to company expansions, including the auction of heavy earth moving equipment and even the flower auction business.

Della Steam Plant is a steam power plant in the southeastern part of the United States. It has turbine-generator units in operation, which produce about 1,000 megawatts of power per day. One of the turbine-generator units began to vibrate heavily after being restarted following a 2-month preventative maintenance overhaul. Lucy Stone, the manufacturer representative, recommended that the unit be disassembled, parts checked and replaced as needed, and then the unit be restarted. The cost of her recommendation was $900,000.

Bob Make, the day shift maintenance engineer, concurred with Lucy’s recommendation; however, Steve Potts, the engineer in charge of predictive management, disagreed. After considering data from sensors he had attached to the turbine-generator unit, Steve concluded that the vibration was due to an oil whip. His recommendation was to restart the turbine-generator immediately. There would be zero cost if he was correct, but the costs might be as high as $19.5 million if he had misdiagnosed the problem and the unit failed during restart.

Sam Towers, plant manager, was in a dilemma. The top management had reduced the maintenance budget, and Lucy’s recommendation was expensive. However, if he followed Steve’s recommendation, the unit might break. Realizing that he needed to consider all technical, financial, and safety aspects, Sam called a meeting of Lucy, Bob, and Steve to arrive at the final decision.

Student tasks are to assume the role of
1. Lucy and defend her recommendation to stop the turbine-generator unit and fix the problem;
2. Steve and defend his recommendation to restart the unit immediately;
3. Sam and decide between the two recommendations and defend his choice;
4. A new technology group and discuss what might be done in the future to solve such problems.

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Solid Rocket Booster. The solid rocket booster (SRB) is a critical component of the space shuttle. Field joints sealed by O-rings hold the booster together and seal hot gases from burning propellant within the booster. Testing revealed problems. William Leon Ray, an engineer whose job was to investigate any problems with the SRB, offered five options as solutions, each having different costs, schedules, and technical design challenges. Candice Rojas, Chief Engineer for the SRB, needed to evaluate these options and make recommendations to NASA.

Students’ tasks are to decide what recommendation Candice Rojas should make considering risk, schedule, ethics, and cost of the options. They are to provide technical details and defend their solution.

Although design modifications had been instituted to help fix the problem with the solid rocket booster, there were still concerns about the O-rings. Joe Kilminster, the Vice President of Space Booster Programs at Morton Thiokol, Inc. (MTI), learned of the seriousness of the situation when engineers at his company wanted to reverse the decision of the NASA Flight Readiness Review and convince management not to launch Flight 51-L the next day. As the engineers and managers debated the issues, Mr. Kilminster clearly realized that MTI had to make a recommendation to NASA regarding the launch of STS 51-L, the Challenger!

In response to this case study, some students are to assume the role of a consultant team and provide recommendations regarding engineering design considerations, statistical data analysis, and ethical considerations. Other students are to assume the role of NASA and MTI management and decide whether or not to launch STS 51-L. Some are to defend the launching while others are to defend not launching.

Case Preparation and Presentation

The class was divided into teams of approximately five students each, and alone and as a group they analyzed each respective case study. Initially, the students were asked to research in the library relevant books and articles, focusing specifically on science, math, engineering, and technology concepts that could be synthesized into solutions. In lab sessions, they reviewed case study materials, particularly the accompanying CD-ROMs, so as to acquire a thorough understanding of the case.

As they worked with each case, students were asked to note in an E-Journal their responses to the following prompts:
1. What questions or comments came to your mind as you progressed through the material?
2. What surprised, interested, or impressed you about your progress on the material?
3. What did you learn while you were working on your material, and how did you feel about it?
4. What did you find most difficult to tackle while you were working on the material?
5. If you were to give advice or directions to someone new to this material, what helpful hints would you offer?
6. What aspects of the material have you enjoyed thus far and why did you enjoy it so much?
7. What information did you learn from the material that you could predict you would use in your future career?
8. As a result of the material you just completed, what have you learned about yourself as a problem solver, an engineering student, and an engineering professional?

Their responses were sent via e-mail to the professor of record for the class and/or the graduate teaching assistants. These E-Journals provided feedback to the professor and enabled him to evaluate student progress. They also were a means by which the students could monitor their own progress and evaluate their learning so far in class.

Each team was responsible for a written evaluation as well as a class presentation for each case study. In the class presentation, team members generally assumed roles of key individuals in the case making recommendations to shareholders/managers who had a stake in the decision made.

They were evaluated on the content and the delivery of their presentation. Considerations in content evaluations were:
1. Problem statement and identification of criteria;
2. Thoroughness, accuracy, and depth of analysis of technical factors;
3. Thoroughness, accuracy, and depth of analysis of non-technical factors;
4. Identification and evaluation of alternatives;
5. Quality, quantity, feasibility, and relevance of recommendations;
6. Justification and support for recommendations;
7. Innovative/interest generated;
8. Connection to theory.

Delivery considerations were:
1. Organization of presentation;
2. Professionalism of presentation;
3. Use of visuals and color;
4. Communication skills of team;
5. Use of time;
6. Handling of questions.

An overall evaluation was given using a rating scale of (1) Poor, (2) Below Average, (3) Average, (4) Above Average, and (5) Superior. Written comments could be provided after each rating.

EVALUATION OF THE EFFECTIVENESS OF THE METHOD

Halpin and Halpin administered evaluation forms to the students at the end of the class. Evaluation I consisted of 15 statements to which the students responded using a 5-point Likert scale ranging from (1) Strongly Agree to (5) Strongly Disagree. Percentages choosing each of the respective response options for each of the items are presented in Table I.

As can be seen in this table, nearly 74% of the students agreed or strongly agreed that they had improved their ability to identify technical and managerial issues. Slightly over half (50.8%) of the students agreed or strongly agreed that they had learned to value other students' points of view (70.9%). While 58.4% of the students agreed or strongly agreed that they had learned how to interrelate important topics and ideas, 52.3% so responded regarding improvement in their understanding of basic concepts. A larger percentage (73.5%) reported that they agreed or strongly agreed that they had learned new concepts while 70.8% agreed or strongly agreed that they had learned to identify central technical and managerial issues. Slightly over half (50.8%) of the students agreed or strongly agreed that they discussed technical and managerial topics outside of class, but only 16.9% so reported that they had done additional reading. Less than half (46.1%) of the students agreed or strongly agreed that they did some thinking for themselves about technical and managerial issues. More agreed or strongly agreed that they had improved their oral communication skills (52.3%) in comparison to having improved their written communication skills (48.5%). Nearly 77% agreed or strongly agreed that they had learned from other students in the class.

Evaluation II consisted of three open ended questions: What were the strengths of the course? What were the weaknesses of the course? Suggestions for improvement? A content analysis was conducted of these qualitative student responses and emergent themes noted.

Student responses regarding strengths of the course clustered around three themes: real world problems, team/group work, and introduction to software. Of those students responding, 47% cited real-life applications as a strength.

- Real life application, gave taste of what the engineering world has become.
- Case studies. I found them helpful.

Of the students responding, 29% noted that the team/group experience was a strength.

- Working with others. Leading the group.
- Learned how to communicate with others. Work as a team.

Of the students responding, 12% made comments about the software or computer applications.

- I learned several computer programs that I feel will continue to help me out in engineering.
- Exposed to different software.

Although numerous strengths were noted, weaknesses were pointed out in response to the second question. Themes which emerged in the qualitative analysis were workload, course organization/assignments, instruction/lectures, and GTAs/labs. Of the students commenting on weaknesses, 37% mentioned workload.

- Lots of work to keep busy. Didn’t learn from the busy work.

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### TABLE 1
PERCENTAGES OF STUDENT (N = 65) RESPONSES TO EVALUATION OF EXPERIMENTAL CLASS

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I improved my ability to identify technical and managerial issues.</td>
<td>23.1</td>
<td>50.8</td>
<td>13.8</td>
<td>7.7</td>
<td>4.6</td>
</tr>
<tr>
<td>I improved my ability to integrate technical and managerial issues.</td>
<td>16.9</td>
<td>53.8</td>
<td>15.4</td>
<td>9.2</td>
<td>4.6</td>
</tr>
<tr>
<td>I improved my ability to evaluate critically technical and managerial issues.</td>
<td>20.0</td>
<td>47.7</td>
<td>23.1</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>I became more confident in expressing my ideas.</td>
<td>15.4</td>
<td>44.6</td>
<td>26.2</td>
<td>7.7</td>
<td>6.2</td>
</tr>
<tr>
<td>I learned to value other students’ points of view.</td>
<td>27.7</td>
<td>43.1</td>
<td>21.5</td>
<td>6.2</td>
<td>1.5</td>
</tr>
<tr>
<td>I learned to interrelate important topics and ideas.</td>
<td>21.5</td>
<td>36.9</td>
<td>35.4</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>I improved my understanding of basic concepts.</td>
<td>20.0</td>
<td>32.3</td>
<td>33.8</td>
<td>7.7</td>
<td>6.2</td>
</tr>
<tr>
<td>I learned new concepts.</td>
<td>29.7</td>
<td>43.8</td>
<td>14.1</td>
<td>4.7</td>
<td>7.8</td>
</tr>
<tr>
<td>I learned to identify central technical and managerial issues.</td>
<td>15.4</td>
<td>55.4</td>
<td>18.5</td>
<td>4.6</td>
<td>6.2</td>
</tr>
<tr>
<td>I discussed technical and managerial topics outside of class.</td>
<td>18.5</td>
<td>32.3</td>
<td>23.1</td>
<td>15.4</td>
<td>10.8</td>
</tr>
<tr>
<td>I did additional reading on technical and managerial issues.</td>
<td>4.6</td>
<td>12.3</td>
<td>27.7</td>
<td>21.5</td>
<td>33.8</td>
</tr>
<tr>
<td>I improved oral communication skills.</td>
<td>20.0</td>
<td>32.3</td>
<td>23.1</td>
<td>15.4</td>
<td>9.2</td>
</tr>
<tr>
<td>I improved my written communication skills.</td>
<td>12.3</td>
<td>46.2</td>
<td>21.5</td>
<td>15.4</td>
<td>4.6</td>
</tr>
<tr>
<td>I learned from other students in class.</td>
<td>27.7</td>
<td>49.2</td>
<td>7.7</td>
<td>7.7</td>
<td>7.7</td>
</tr>
</tbody>
</table>

1 - Strongly Agree, 2 - Agree, 3 - Neither Agree, 4 - Disagree, 5 - Strongly Disagree

- Too time intensive for the level of the class. Make it a 3-hour course.

Of the students noting weaknesses, 28% focused on class organization and assignments.
- The class was disorganized at times. Assignments were not clear.
- Sometimes needed more specifics.
- Of the students responding, 17% cited course instruction.
- The lecture didn’t help a whole lot.
- Some classes seemed useless.
- Some of the labs were not explained well by the GTAs.

Suggestions for improvement made by the students were somewhat varied, but some themes did emerge from the analysis. In general, their comments were related to organization, time allocation, and projects/assignments. Of those responding, 29% offered comments regarding organization.
- Less lecture, more lab.
- Show us how to do the labs in class.
- More one-on-one with professor.

Of those offering suggestions, 23% focused on time allocation.
- Spend more time on case studies and design project.
- More time on teamwork.

Again, of students providing comments, 22% offered suggestions related to projects and assignments.

#### EVALUATION OF STUDENT OUTCOMES

The outcome measures used in this evaluation were collegiate grade point average (GPA) and admission to study in a professional engineering program. Regarding GPA, the assumption is that those students having higher grade point averages have mastered to a greater extent course objectives in their programs of study. Certainly, mastery of objectives in the experimental course would contribute to the overall grade point averages of students in the experimental group. Comparisons of the grade point averages of the experimental group to those of matched comparison students who were not in the experimental classes in turn provide data important in the evaluation of the experimental course.

Altogether, these qualitative responses provide data crucial in the formative evaluation of the experimental course. Strengths should be built upon. The weaknesses provide insights regarding areas where changes are needed. More specific suggestions were provided by the students in suggestions for improvement.
The experimental program was inclusive of such affective goals. Hence, admission status is another student outcome that provides valuable information that validates the experimental program.

With GPA and admission status as dependent variables in this research design, student group became the independent variable. In order to evaluate the GPAs and admission status of the experimental student group participating in the multimedia case-study classes, a comparison group was selected. A stratified random sampling process was used. Matching variables were high school grade total, ACT Composite, ACT Math, SAT Quantitative, and engineering major (i.e., mechanical engineering, other engineering major). Comparison students were randomly selected from a matched pool of pre-engineering students who had not taken the experimental course. Their introductory engineering courses had been taught generally via lecture and discussion with course grades tending to be slightly higher initially than grades in the experimental classes.

Analyses of variance were used to determine if there were significant differences in GPA for the experimental and comparison groups. For the analyses, the experimental and comparison groups were subdivided into ME (mechanical engineering, the predominate major) and Other (another engineering major). GPA was considered at the end of the first three semesters of study as well as for overall pre-engineering. Results are reported in Table II.

As can be seen in Table II, the probability levels for all F ratios were < .01 with most being < .001 indicating that GPA differences among the group means were not likely to be due to chance. Mean comparisons indicated that the first semester GPA mean for the experimental ME (2.89) group was significantly higher than the means for the comparison ME (1.96) and Other (2.35) groups. The mean for the experimental Other (2.76) group was significantly higher than the mean for the comparison ME (1.96) group but not for the comparison Other (2.27) group.

Second semester GPA mean for the experimental ME (2.90) group was significantly higher than means for the comparison ME (2.07) and Other (2.27) groups. The mean for the experimental Other (2.76) was significantly higher than the mean for the comparison ME (2.07) group but not the comparison Other (2.27) group.

Mean GPA for pre-engineering covering the first 2 years of study for the experimental ME (2.79) was significantly higher than the mean for the comparison ME (1.99) group but not for the comparison Other (2.50) group. Pre-engineering GPA mean for the experimental Other (2.69) group was also significantly higher than the mean for the comparison ME (1.99) group but not for the comparison Other (2.50) group.

Following a prescribed 2-year program of study in pre-engineering, students with GPA > 2.2 may be admitted to a program of study in a professional engineering discipline or they may voluntarily choose to leave engineering. Those with GPA < 2.2 are denied admission. Shown in Table III is admission status for the experimental and comparison groups. As can be seen in this table, significantly greater numbers of students in the experimental groups were admitted to engineering. Conversely, more in the comparison groups were denied admission because of poor grades. More in the comparison groups also left with good grades, but differences here were not as great.

**SUMMARY**

Case studies focusing on real-world problems were central in a select number of introductory engineering classes. Students in these classes formed an experimental group whose grade point averages were compared with those of other pre-engineering students who were not in these experimental sections but instead were in other sections taught using more traditional lecture/discussion approaches. End-of-course evaluations in the experimental classes showed that they were well received by the students and beneficial in helping them achieve course objectives. Benefits extended beyond the experimental class as evidenced by significantly higher GPAs in subsequent terms in contrast to the GPAs of the comparison group. A most

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**TABLE II**

**ANALYSIS OF VARIANCE FOR GRADE POINT AVERAGES OF EXPERIMENTAL AND COMPARISON GROUPS**

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>First semester GPA</td>
<td>Effect</td>
<td>3</td>
<td>9.983</td>
<td>10.872</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>223</td>
<td>.918</td>
<td></td>
</tr>
<tr>
<td>Second semester GPA</td>
<td>Effect</td>
<td>3</td>
<td>8.028</td>
<td>8.183</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>204</td>
<td>.981</td>
<td></td>
</tr>
<tr>
<td>Third semester GPA</td>
<td>Effect</td>
<td>3</td>
<td>5.207</td>
<td>4.244</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>127</td>
<td>1.227</td>
<td></td>
</tr>
<tr>
<td>Pre-engineering GPA</td>
<td>Effect</td>
<td>3</td>
<td>7.009</td>
<td>9.609</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>217</td>
<td>.729</td>
<td></td>
</tr>
</tbody>
</table>
TABLE III
ENGINEERING ADMISSION STATUS FOR EXPERIMENTAL AND COMPARISON GROUPS

<table>
<thead>
<tr>
<th>Status</th>
<th>Experimental ME</th>
<th>Other ME</th>
<th>Comparison ME</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admitted to engineering</td>
<td>36</td>
<td>32</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Not admitted GPA &lt; 2.2</td>
<td>12</td>
<td>14</td>
<td>26</td>
<td>15</td>
</tr>
<tr>
<td>Left engineering GPA ≥ 2.2</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

Important finding is the differential rate at which the experimental pre-engineering students were admitted to study in a professional engineering program. Those pre-engineering students were admitted in much higher proportions than were their comparison counterparts.

Although replications with more participants are important, there were sufficient numbers in this study to ensure statistical power and make the results meaningful as well as significant. Findings herein support the use of multimedia case studies as important innovations in engineering education today that would certainly help prepare engineers who can solve real-world problems.

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