Use of Multimedia Case Studies in an Introductory Engineering Course at Two Southeastern Universities: A Qualitative Evaluation Study

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Abstract

It has been suggested that changes in the classroom environment and nature of instruction may positively affect student learning of introductory engineering concepts. In response to recent calls to improve engineering instruction, an interdisciplinary team of researchers worked together over a three-year period to improve the introductory engineering courses offered at two universities in the Southeast: the first being a large public research university and the second an historically black university. This qualitative action evaluation study focuses on the third culminating year of the study from fall 2011 to spring 2012.

Employing an action evaluation approach a team of external researchers collected qualitative data from students through open-ended surveys and focus groups to determine the effectiveness of the instructional methods and guide continuous course improvements. The 4P model provided a theoretical framework for the evaluation questions. The questions focused on students’ perceptions of the value and nature of learning with multimedia case studies and perceptions of the course overall.

In fall 2011, after completing the course in which multimedia case studies were used, 102 students responded to an open-ended survey and 64 participated in focus groups. In spring 2012, 110 students responded to the survey, and 24 contributed to focus groups.

Focus group data were analyzed using a thematic analysis approach, and frequency counts were conducted to analyze the open-ended survey data.

Findings indicate that students’ prior experience with case studies influenced how they perceived the use of multimedia case studies. Students at both universities indicated that case studies were beneficial. Other findings illustrated that what they found to be interesting was not necessarily what they found to be helpful to their learning. Coursework—particularly that which emphasized communication skills and group work—was deemed to be important to students’ future university coursework as well as to their future work environments.

In line with the qualitative paradigm used for this study, the results also include student perceptions of the larger course context, as these are relevant to the way in which students frame their perceptions of the particular instructional method of multimedia case study. Recommendations and discussion related to design considerations in introductory engineering courses are included.
Introduction

In response to recent calls for changes in engineering education to address the knowledge and skills that today’s engineers need in the workplace, this research-based evaluation focused on changes in both faculty input and student output. Our goals addressed improvements to how faculty approach engineering education, as well as the results of those changes in enhancing student achievement in learning engineering concepts in introductory engineering courses. Watson encouraged teacher-researchers to translate their findings into applications for curriculum development and advocated using research to make changes in course content, pedagogy, organizational structures, and the overall engineering culture: “Education innovation deserves the same discipline, imagination, and effort that we are willing to put into other complex engineered systems.”

To effect such broad-based changes, an interdisciplinary team of engineering and business faculty, teaching assistants, and educational researchers was established to address improvements to introductory engineering courses at two universities in the southeastern United States (a large public research-focused institution and a small, private teaching institution). Course improvements initiated by the team included curriculum changes, such as incorporating multimedia case studies which provided the potential for cost-effectiveness and broader appeal.

This paper discusses the key qualitative findings from the culminating third year of a three-year NSF-funded project to improve introductory engineering courses at two universities carried out by the interdisciplinary team.

Engineering Instruction

The field of engineering education has changed from its 19th-century emphasis on industrial skills to the post-World War II focus on scientific and mathematics skills to a shift in the 1970s and 1980s that centered on such skills as critical thinking, communications, and team work. Recent industry reports indicate that engineering graduates are lacking in the areas of creative thinking and design, communication, and other professional skills. Graduates have been found to be weak in their understanding of certain engineering processes and to lack design creativity; they may have a narrow view of the skills needed to work in project management and with teams of interdisciplinary workers.

The changes in the skills needed by today’s engineers have encouraged university engineering faculty to alter how engineering is taught, moving from the strictly theoretical lecture approach of the past to a more hands-on approach. However, engineering as a field has been slow to adopt alternative pedagogies to the ubiquitous lecture method.

One encouraging model for engineering faculty development is the NSF-funded SUCCEED program in which learning communities were established; faculty members saw various techniques modeled, and discussion and critique were integral activities. Faculty who participated in these faculty development programs reported using more active learning exercises in their classes, more team work activities, and more study guides to help students learn the course content.
A review of engineering education literature provided a summary of instructional practices that lead to engineering expertise by engineering students. It has been suggested that engineering education experiences needed to provide opportunities for students to gain “deep conceptual knowledge” that facilitates knowledge transfer and be able to use both technical and professional skills, while working on real world projects in engineering. They further point out that current engineering education often does not achieve these objectives.

**Action Evaluation**

The choice of methodological approach should be fully explained, including the decisions about how it was selected and designed. The motive for including a qualitative component to the 4P model was to provide depth to the quantitative survey responses to enable us to better understand how students were experiencing the pedagogical changes made, how they perceived these changes to affect their learning, and to glean feedback from them about how we could better meet their instructional learning needs.

The methodological approach for the qualitative evaluation in this study was action evaluation, based on Rothman’s action evaluation approach. Action evaluation incorporates the establishment of goals with assessment to refine goals and provide a retrospective element. The action research aspect of the project involved implementing cycles of action, during which multimedia case studies or assigned readings for discussion were used and about which data were collected to determine their effectiveness for teaching/learning engineering concepts. The procedures for using cases and other classroom activities were revised each semester, based on the feedback from students, to improve learning.

This approach facilitated continuous data collection and feedback to make improvements in subsequent iterations of action in the study. Weekly meetings of the investigation team enabled evaluators to stay current on pedagogical changes made throughout the study and facilitated sharing of feedback to make course improvements. Qualitative data were collected through a series of open-ended surveys and focus groups to determine the effectiveness of the instructional methods. Data were collected after each semester, and results were disseminated to the team to guide course modifications for the next semester.

Qualitative research, known for its flexibility in theoretical frameworks and methodologies, emphasizes the importance of context, researcher/participant engagement, perceptions of participants, inductive data analysis, and reflection by researchers and participants. Quality of research findings in qualitative research is established through the “high standards of rigor, including theoretical consistency, transparency in methods, acknowledging researchers’ involvement in and contributions to knowledge produced, citing of appropriate references for data collection and analysis methods, creating an audit trail to ensure the interpretation is consistent with the data, and appropriate use of the language and traditions of qualitative research.”

**The 4P Model**

The theoretical framework of this study focused on the 4P model, which is an extension of the Biggs and Moore 3P model. The 4P model encompasses the concepts of presage, pedagogy, process, and product. The presage component considers characteristics of learners that exist prior
to the learning experience, such as age, gender, learning styles, behavioral tendencies, and race. The pedagogy aspect refers to the specific instructional methodologies used in the study, such as the multimedia case studies used as the treatment condition and the assigned topics discussions that served as the control condition. The process component centered on students’ deep learning – “motivation to learn and understanding of causal relationships among concepts.\textsuperscript{14}” The fourth component addressed product or achievement in student learning outcomes. It has been suggested that the product component is affected by the intersection of the presage component and the process component.\textsuperscript{15} This led the investigators in our study to suggest that the pedagogy component may affect the product component. Figure 1 illustrates the 4P model used to guide the study.

This model guided the evaluation questions, and the researchers believed that the use of qualitative methods would facilitate a richer understanding of learners’ experiences. Research suggests students’ existing presage factors have not traditionally been evaluated with qualitative methods in engineering education;\textsuperscript{16} hence, these were considered in developing the pedagogical tools used to improve their critical thinking, communications, and teamwork skills.

<table>
<thead>
<tr>
<th>Presage</th>
<th>Pedagogy</th>
<th>Process</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Instructional Methodologies</td>
<td>Gain in Higher Order Cognitive Skills</td>
<td>Improvement in Achieving Outcomes</td>
</tr>
<tr>
<td>Behavioral Tendencies</td>
<td></td>
<td>Improvement in Self-efficacy</td>
<td></td>
</tr>
<tr>
<td>Learning Styles</td>
<td></td>
<td>Improvement in Team Working Skills</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textit{Figure 1}: Presage-Pedagogy-Process-Product (4P) Model

\textbf{Evaluation Questions}
Two evaluation questions were created to guide the evaluation. The questions were written to be nondirectional to yield description rather than “related variables or compare groups”\textsuperscript{17}:
1. How do students perceive the value and effectiveness of the use of multimedia case studies in the introductory engineering course?

2. What strengths and areas of improvements do the students perceive are needed in the course, in general, and in the instructional methods, in particular?

**Method**

**Research Design**
An action evaluation design\(^\text{12}\) was used to guide the systematic collection of data through focus group interviews and open-ended survey questions. This approach facilitated continuous data collection and feedback for improvement in subsequent iterations of the course. Data were collected and analyzed after each semester, and results were disseminated to the larger team to guide course modifications for the next semester.

**University Contexts**
The evaluation study was conducted at two southeastern universities: a large public university herein referred to as RU (research university) and a small, private teaching institution herein referred to as TU (teaching university).

RU is a large, selective, research-intensive university located in the southeastern United States. The engineering college offers thirteen bachelor’s degrees. The introductory engineering course in which this evaluation study took place includes students seeking degrees in electrical, mechanical, aerospace, civil, and wireless engineering fields. The two-hour course is delivered in a lecture/lab format: students attend a fifty-minute lecture session early in the week in a large lecture theater, and later in the week, they attend a two-and-one-half-hour lab session. Each lab section has an enrollment between 14 and 20 students, allowing for a smaller-class setting than the lecture theater. Because students are in class more than three hours per week, course activities and assignments often take place in class.

TU is a small, private, historically black college (HBCU) located in the southeastern United States. The engineering college offers at least three undergraduate degrees in engineering, including chemical, electrical, and aviation-related disciplines. Most students in the introductory engineering course were seeking degrees in engineering, and a small number were pursuing business degrees. The two-hour course sections were delivered in a traditional classroom setting (in contrast to the lecture theater/lab split at RU). Because students are in class fewer than two hours per week, course activities that were not completed during the class session were often completed outside of class.

**Course Context: Major Assignments & Course Activities**
In spite of some contextual differences described above, the courses were planned together and syllabi were identical with one exception noted below (e.g., addition of robot labs at RU). Below, major assignments and course activities are noted to provide an understanding of the nature of the courses at RU and TU.
1. Lectures. The same lectures were delivered each week at both universities. Topics included engineering disasters, ethics, the engineering design process, and statistics and team work, among others. In spring of 2012, two class lectures were delivered via video to students at RU and TU. The topics were engineering design and communication.

2. BlackBoard Learning Management System (Bb LMS). The Bb LMS was used to store additional resources such as PowerPoints used in lectures.

3. Textbook. Both universities used the same introductory engineering textbook.

4. Hands-on Lab Activities. Students at both universities completed the Hang Time Maximizers lab (HTM), the Pasta Tower lab (PT), and the Boat Project (BP). The purpose of HTM was to design a piece of paper in such a way that it stayed aloft as long as possible. The purpose of the PT was to construct a tower of spaghetti and masking tape. The tower had to be at least 12 inches in height. The tallest towers bearing the greatest weight (per a specific formula) were deemed the best. The purpose of the BP was to teach students about buoyancy.

5. Midterm and Final Exam. Students at both institutions took the same midterm and final exams. Concepts on these exams address lecture and textbook topics.

6. Unique Activity at RU: Programming with Lego Robots. With the additional time embedded in their schedule, RU students also engaged in computer programming with robot labs.

7. Multimedia Case Studies Presented as Round Table Discussions. Students worked in teams to understand issues presented in assigned case studies. Students were assigned a stance or position to defend in the round table discussion format. Round table discussions took place in class. In fall of 2011, the Chick fil A, Della, and STS 51-L case studies were used by students at both universities to address concepts related to decision-making processes (Chick fil A and Della) and ethics (STS 51-L). In spring of 2012, the Chick fil A and Mauritius case studies were used by students at both universities. Concepts of solving design problems were addressed in Mauritius. Case studies were developed by the LITEE Lab. The use of audio, video, and visual media is what characterizes them as multimedia (as opposed to traditional case studies that may be only text-based).

**Course Changes from Fall 2010 to Spring 2012**
A team approach to studying and improving the introductory engineering courses highlighted in this study has been used for nearly four years (the fall and spring semesters under study here represent the third year of this collaborative effort). Generally, major changes to the courses occur in the late summer prior to a new fall semester. There is sufficient time to make major changes from late July to early August. Even so, a few minor changes were made between fall 2011 and spring 2012: the multimedia case studies topics and number changed. In fall of 2011, three case studies were used (Chick fil A, Della, and STS 51-L), while in spring, two case studies were used (Mauritius and Chick fil A). The reasons given by course designers for making this change in number and type of case study were a) reduced time in the spring schedule to include all three case studies, and b) desire to try out the Mauritius case study, which would support course objectives.
In addition, to increase consistency across the RU and the TU introductory engineering courses, two lectures—typically delivered live by the faculty teaching at each institution—were video-recorded. One lecture was recorded by an RU faculty member, while the other was video-recorded by a faculty member at the TU institution. Length of the video lectures was approximately 15 minutes, and the topics addressed were engineering design and engineering communication. Students at both institutions viewed the videos in class instead of viewing the lecture delivered by their resident faculty member. Video lectures were discussed in class.

**Participants**

In the cases of all participants at both universities and during both semesters, group assignment was nonrandom and based on the course section in which students were assigned. Participation in surveys and focus groups was optional, and students were not to be compensated. (In the limitations section, it is noted that one spring TU group was compensated with extra credit points.)

Looking at Table 1, it becomes evident that participants responding at RU are predominantly male (92.4% in fall 2011; 87.0% in spring 2012) and white (92.4% in fall 2011 and 93.5% in spring 2012). In addition, all participants at RU are engineering majors. Participants responding at TU are predominantly black (90.1% in fall 2011; 90.9% in spring 2012) and respondent sex is split fairly evenly across male and female: in fall 2011, the split is even (50.0% male and 50.0% female), while in spring 2012, females predominate slightly (63.6% compared with 36.4% males). Detailed data on student majors are not provided in this study. However, to give a general idea, the majority of fall 2011 TU respondents are engineering majors (with 3 exceptions with students in business-related fields), while the majority of spring 2012 TU respondents were majoring in business-related fields (with two students majoring in engineering).

Numbers of participants dropped between fall and spring due to the introduction of an engineering game in some course sections during spring 2012 (for another study). Students who experienced the engineering game were not included in the spring sample. In addition, the number of students at TU is typically lower in spring semesters due to programmatic scheduling factors. See Table 2.

**Data Collection Procedure**

Primary forms of data collected were open-ended survey questions and focus group interview data. Surveys were administered by course instructors and lab teaching assistants through a login-based online survey tool during the face-to-face class session. Students were given approximately 30 minutes to complete the surveys. Survey questions focused on students’ previous experience with engineering, perceptions of most helpful teaching methods, preferences related to working in groups, suggestions for enhancing learning in the course, perceptions of relevance of coursework to future work, most interesting part of the course, aspects most helpful to learning, helpfulness of the multimedia case studies, helpfulness of group work for problem-solving, and overall suggestions for improvement.
Table 1  
*Student Demographic Data at RU and TU, Fall 2011 - Spring 2012*

<table>
<thead>
<tr>
<th>Institution</th>
<th>RU</th>
<th>RU</th>
<th>TU</th>
<th>TU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responses / Total Students in Course</td>
<td>79 / 85</td>
<td>31 / 92</td>
<td>22 / 22</td>
<td>22 / 22</td>
</tr>
<tr>
<td>Sex</td>
<td>73 (92.4%) Male</td>
<td>27 (87.0%) Male</td>
<td>11 (50.0%) Male</td>
<td>8 (36.4%) Male</td>
</tr>
<tr>
<td></td>
<td>6 (7.6%) Female</td>
<td>4 (12.9%) Female</td>
<td>11 (50.0%) Female</td>
<td>14 (63.6%) Female</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>73 (92.4%) White</td>
<td>29 (93.5%) White</td>
<td>0 (0.0%) White</td>
<td>0 (0.0%) White</td>
</tr>
<tr>
<td></td>
<td>3 (3.8%) Black</td>
<td>0 (0.0%) Black</td>
<td>20 (90.1%) Black</td>
<td>20 (90.9%) Black</td>
</tr>
<tr>
<td></td>
<td>1 (1.3%) Asian-American</td>
<td>1 (3.2%) Asian-American</td>
<td>1 (0.05%) Asian-American</td>
<td>1 (0.05%) Asian-American</td>
</tr>
<tr>
<td></td>
<td>3 (3.8%) Hispanic</td>
<td>1 (3.2%) Hispanic</td>
<td>1 (0.05%) Hispanic</td>
<td>0 (0.0%) Hispanic</td>
</tr>
<tr>
<td></td>
<td>1 (1.3%) Other</td>
<td>0 (0.0%) Other</td>
<td>0 (0.0%) Other</td>
<td>1 (0.05%) Other</td>
</tr>
</tbody>
</table>

Note: Percentages given are taken out of the total of students responding.

**Survey Participation**

In fall 2011, 79 RU students and 23 TU students responded to an open-ended post-semester survey. In the spring of 2012, 31 RU students and 5 TU students responded to the survey. See Table 2.

**Focus Group Participation**

Focus groups were conducted by the external evaluators near the end of each semester. Groups were recruited and formed based on class section. Instructors invited all students to attend during a scheduled meeting time. This resulted in groups ranging in size from six to 18. A semi-structured protocol was used to guide the asking of focus group questions. Questions related to student experiences in the course overall, perceptions of working in groups, of learning through multimedia case studies, and suggestions for improvement. In fall 2011, 20 RU and 24 TU participants provided feedback, while in spring 2012, 6 RU and 6 TU students provided data in focus group sessions. See Table 2.

In fall 2011, focus groups were conducted via teleconference, and in spring 2012, they were conducted in person on the university campuses of RU and TU.
Table 2
Student Participants by Data Collection Method at both Universities, Fall 2011 - Spring 2012

<table>
<thead>
<tr>
<th>Data Collection Method</th>
<th>Research University (RU)</th>
<th>Teaching University (TU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall 2011</td>
<td>Spring 2012</td>
</tr>
<tr>
<td>Survey</td>
<td>79 students</td>
<td>31 students</td>
</tr>
<tr>
<td>Focus Groups</td>
<td>20 students</td>
<td>6 students</td>
</tr>
</tbody>
</table>

Data Analysis
The researchers collected two forms of data (open-ended surveys and focus groups) to foster triangulation of data and increase the trustworthiness of interpretations drawn from analysis. With the open-ended surveys, data were analyzed using thematic analysis, where appropriate, using NVivo9 qualitative analysis software. The open-ended survey data provided mixed types of information, some of which was not quantifiable (in that students provided overlapping, ill-structured, open responses). However, other open-ended survey data proved to be quantifiable, and the researchers felt the use of frequency counts was appropriate to display these data. The researchers used open coding to analyze these data.

The first author conducted the focus group sessions and recorded them using a digital audio recorder. She then transcribed the recorded data, typing them into Microsoft Word. Focus group data were transcribed and imported into NVivo9 qualitative analysis software. They were first analyzed using open codes such as content, major, guest speaker, affective, course design concepts, prior knowledge, assessment, textbook, and interaction (to name a few examples). These codes were collapsed into larger themes using inductive thematic analysis. Further analyses (this time, deductive in nature) were conducted to fit the identified themes under the rubric of the 4P model: with major headings of Presage, Pedagogy, Process, and Product. These codes were further elaborated into themes, which are presented in the findings below. This inductive-to-deductive approach allowed us to understand the findings in relation to the 4P model.

Results

Presage
Presage components include characteristics of learners that exist prior to the learning experience, such as prior knowledge, age, gender, learning preferences, behavioral tendencies, and race. Some students found course topics to be redundant (e.g., statistics) as they had already learned them in previous courses in high school. This colored their perception of the content as either redundant or reinforcing of their understanding. Some students cited preferences for working alone rather than in groups, although one self-described individualist noted the benefits of group work in spite of the challenges:
I know I am a person who doesn’t like working in groups. But being in the same groups all year was a plus because you learn your group members’ ways. And you learn to work better with someone. Like living in a household or family.

Student majors affected their perception of the relevance of the course materials. Students not majoring in software engineering or electrical engineering found less benefit in the robot programming activities at RU. In addition, the various engineering majors tended to desire more hands-on lab projects related to their particular engineering field. In spite of being “outside of their major” some of the TU business majors noted the appropriateness of critical thinking challenges in hands-on labs and multimedia case studies:

*The competition aspect of this course really does go with our business major. And so does the critical thinking part….how do you make the boat and the plane? And the case studies stimulated critical thinking.*

**Pedagogy**

Pedagogy aspects refer to the specific instructional methodologies used in the study, such as the multimedia case studies, lecture, and textbook reading.

*Pedagogy Overall.* The 79 fall 2011 RU students made 114 mentions of various pedagogical methods used in the course that they found helpful to their learning. Eighty of these comments related to projects, group work, or other lab-related activities, and 50 comments related to the helpfulness of the lecture class. These frequencies of mention are representative of the general preferences indicated by RU students, based on data from focus groups and surveys. When asked which aspects of the course were most helpful to their learning, RU students responded (with 94 comments total) that the lab activities (including mentions of labs, case studies, presentations, group work, hands on projects, robots, and projects) were most helpful (62% of students responding mentioned these), followed by lecture activities (including power points, lecture, text/study guides, and homework) (44% of students commented thusly on this question).

In spring 2012, of the 111 mentions by RU students about most helpful instructional methods, 72 comments were about aspects of the lecture class, and 35 comments indicated that lab activities were most helpful to their learning. The switch in perceptions of students about what teaching styles they found to be most helpful to their learning from fall semester to spring semester may stem from any of several reasons: improvement of the instructor’s delivery in the lecture portion of the course, such as increasing the involvement of students in class discussions; the curricular changes made in the content, which included more variety in delivery modes; or their frustration with carrying out the lab assignments, particularly the robot project. When asked which aspects of the course were most helpful to learning, RU students made 87 comments, 50 of which (57%) related to lab activities, 32 of which (37%) related to lecture activities and resources, and 5 of which (6%) related to course topics.

TU students also were asked about their preferred teaching style and about what aspects of the course they found to be most helpful to their learning. Regarding the teaching style they found most helpful, of the 23 TU students reporting in fall 2011, 35 comments were made, 18 of which (51%) related to lecture class, and 15 of which (43%) related to projects, group work, and lab activities, indicating a small preference for lecture over lab work. When asked about which
aspects were most helpful to their learning, of the 25 comments made, an equal number of students mentioned aspects related to lecture activities as did lab activities (52% each).

Of the 33 mentions by TU students about what instructional method they found most helpful in spring 2012, lecture was mentioned 16 times and lab activities or group work 17 times [lecture activities = power points, text/study guides, homework; lab activities = case studies, presentations, group work, projects].

These comments do not indicate much difference in the instructional methods they found to be most helpful to them in learning engineering concepts. When asked which aspects of the course were most helpful to their learning, TU students’ 20 comments indicated that they found lab activities to be helpful (55%), followed by specific course topics (25%), and then followed by lecture activities and resources (20%).

**Helpfulness of case studies (pedagogy).** We specifically asked them about how helpful they perceived the case studies to be. In fall 2011, 74% of students at RU (30% somewhat beneficial; 29% beneficial; 15% very beneficial) and 82% at TU (13% somewhat beneficial; 39% beneficial; 30% very beneficial) found the case studies to be helpful. Only 24% of RU students and 17% of TU students indicated that the case studies were not helpful to their learning.

In spring 2012, when asked how helpful they perceived the case studies to be to their learning, 70% of RU students and 60% of TU students noted that the case studies were beneficial to learning, while 32% of RU students and 20% of TU students marked that they were not helpful.

**Case study as conceptual connector.** Several students saw the multimedia case studies as an opportunity to better connect lecture and lab sessions:

> With the case studies, maybe they could have talked about more information relevant to the business aspects of engineering (in lecture). They could have provided a bit more of a connection between lecture and lab, and it would have made it a lot more interesting and beneficial to us.

> The only thing I could find that was a direct relationship would be the case studies...and talking about that. Other than that...there were really no correlations between the lecture and labs.

**Relevance of case studies.** As noted above (see section on lectures), one student saw a correlation between course lectures and lab sessions during which the case studies were the focus of activity. Another student explained how case studies apply to his future engineering role. Case studies show

> . . . you what engineers deal with day-to-day. The problems and the risks they take making decisions. Yeah, you learn a lot by building all the structures and stuff—about teamwork—but learning engineering things that actually happened in the world makes you realize what an engineer actually does.

**Implementation challenges.** One student felt that the case studies could have been set up better in the lecture session:
With the case studies, maybe they could have talked about more information relevant to the business aspects of engineering (in lecture). They could have provided a bit more of a connection between lecture and lab, and it would have made it a lot more interesting and beneficial to us.

Another student felt that class time was wasted on case studies in the sense that students could have accessed and perused case study materials individually online and used class time for other things:

*We had our case studies. We had about three class periods dedicated to working on these. We could have used these class sessions for more hands-on activities. We could access the case studies online. I felt like it was a waste of time to do the case studies in class.*

Finally, a student offers an alternative approach to designing the case study assignment:

*I thought that if somehow the projects were broken up so that everyone was doing something a little bit different, and then briefing on their designs and their problems, and things that they had on what they were really doing, that you’d get the same effect, but it’d actually be better. Plus, it wouldn’t bore everybody to listen to the same stuff five different times as it’s going through.*

**Translating case study learning into round table presentation.** One student noted that the case study “…information was very condensed, so you didn’t have a whole lot to talk about for three minutes per person, which was 15 minutes for each of the 4 groups. You kind of ran out of stuff to talk about.” The same student also said, “I felt it was too much. They were giving me the opinion. They were giving me the information. I was just regurgitating it for the purpose of pretending to be an engineer.” Another student was in a group that had to be broken up due to lack of topics to assign to groups: “We only had four topics to speak on in the case study, and we had five groups, so our group had to break up among the four others so that it would be four teams of five.” As noted in the section on “group work,” this unexpected shifting of groups was unpleasant for some students.

**Student perceptions of round tables.** Several TU students expressed positive feelings towards the use of the round table format to present the learning from the multimedia case studies. One student said,

*I kind of liked it, because it was less of us teaching the class about what was going on, and it was more of a discussion. So, it was about being more comfortable discussing the topics. It didn’t feel like we were giving a presentation and getting a grade. It was kind of like we were sharing how we felt about the strategies, the ands, the if’s, and the buts.*

Another student emphasized the way in which the round table compelled students to take a side:

*Everyone had their own topic, and they had to make a report on why this topic is better than the other. Even if you didn’t believe your topic was better, you had to come up with solutions and discussions of why your topic was the best. It just became a fun debate about why our position was better. Since you think this is better, can you explain it? It was a fun debate.*
One student conveyed her perception that students really had to prepare for the round table discussions or risk being found out:

You had to really know the information and build your own opinions. If you’re just talking just to talk, Dr. Le is going to pick up on that and once she picks up on that, that’s when more questions start to come and then you’ve just got to try to get around it. It’s like she knows when you’re babbling on. She’ll just keep asking questions.

Distracted by dated content. For several students, they were distracted by the case study’s treatment of what they saw as an outdated problem.

Although I do have to say that working on the Chick fil A case study and talking about software that’s about fifteen to twenty years out of date was a little bit of a stretch. We were talking about upgrading to Windows NT.

Student perceptions of Chick-fil-A case study. Overall, RU students preferred the second case study undertaken in the course, the Chick-fil-A case study. Reasons given for liking it included these:

- Because it had the three different computer programs. Each group was assigned one it had to defend.
- Because I can see this situation working out in a future career/company situation.

One student described the Chick-fil-A case study as “useful” in spite of a few perceived drawbacks. Among these, one RU student “[wished] that there had been more material. Five groups created some overlap. I wish that each group had its own product to defend.”

One challenge several TU students noted was the tediousness of the Mauritius case study. Another student expressed confusion about the purpose of the case studies, in particular, the Mauritius case study:

I didn’t really understand…personally I feel like I completed both of these projects with just the grade in mind and not really to learn anything. When we presented the first case study, I didn’t really understand how that was going to help me. It was like we were just evaluating the case study and the videos that they had on the CD.

A TU student says she would be open to learning through case study in the future “if we were able to relate to it more. . . . If there were more problem-solving on our part, then yes.”

Perceptions of case study quality. One RU student made the majority of comments about her experiences with the Mauritius case study, while the other two students tended to nod in agreement throughout her explanation. She said her group did not understand the Mauritius case study:

Nothing was argued or discussed. They just told each other facts that everyone already knew. It was really hard to understand the videos. It only gave half of the story. My group was confused about what had happened and why there was a problem. The purpose was to show content and communication, but it was lacking in those aspects.

The student added that the video quality was poor, and actors’ voices were accented, making it difficult to understand. Add to this the fact that “[RU students] were in one room with multiple groups watching the case study videos at the same time, causing noise and hearing different
things.” She concluded her analysis by noting the incongruence of messages in the case study: “there might be a video about what is going on with the auditorium?, and then there is a random video about female engineers.” This “random, out-of-the-blue fact about female engineers” further distracted her group from the main point of the case study.

When asked if they had viewed the case studies at home, one student explained, “I have a Mac, and it wouldn’t let me play the videos at home. I could foresee that being a problem.”

Another student provided a suggestion for improving the presentation of the case study:

*I felt like we didn’t really do any problem-solving. The answers were there. It was more about us figuring out how to present. So, if they could kind of like leave out the answers and let us figure it out, and then we figure out the actual option….maybe the teacher can tell us, then maybe that would be more effective.*

**Process**

The process component centered on students’ deep learning of concepts. As such, student mentions of variety (e.g., lecture), interest (e.g., humor, stories, guest speakers, and activities), and active learning (e.g., group work, engagement, hands-on) were analyzed through this lens.

Improvement in team-working skills is a subcomponent of the process component of the 4P model. Engineering employers encourage the teaching of team building.

RU and TU students in fall 2011 and spring 2012 indicated that they preferred working in groups over working alone. The percentage of RU students preferring group work decreased from fall to spring, but the percentage of TU students preferring group work increased slightly from fall to spring. As we have heard from students in the past, they tend to enjoy group work for solving large problems, to brainstorm for possible solutions, or when a problem is complex. They appreciate having the views of others and being able to test out their ideas in a group. At TU, during spring semester, students, the majority of whom were business majors, noted the importance of being able to work in groups, no matter their major. They indicated that working in groups on case studies and round table exercises prepared them for working with diverse groups in the future.

In fall 2011, when students were asked whether the group work was helpful for problem solving, 80% of RU students (9% somewhat beneficial; 34% beneficial; 37% very beneficial) and 87% of TU students (4% somewhat beneficial; 30% beneficial; 52% very beneficial) responded that it was beneficial to some degree.

In spring 2012, 77% of RU students (5% somewhat beneficial; 36% beneficial; 37% very beneficial) and 78% of TU students (4% somewhat beneficial; 26% beneficial 48% very beneficial) indicated that the group work was helpful for developing their problem solving skills.

**Product**

*Helpfulness of Multimedia Case Studies.* Table 3 illustrates fall 2011 students’ responses to how beneficial they believed the multi-media case studies were to their learning. Most students found the case studies to be at least somewhat beneficial (13% of RU students and 13% of TU students). However, 23 RU students (29.1%) and 9 TU students (39.1%) found them to be
beneficial. Twelve RU students (15.2%) and 7 TU students (30.4%) rated them as being very beneficial. The majority of students at both universities found case studies to be beneficial to some extent. While most students found the case studies to have value in their learning, 13 RU students (16.5%) and 2 TU students (8.7%) indicated that they were not very helpful, and 6 RU students (7.5%) and 2 TU students (8.7%) rated them as not being helpful at all.

Table 3
Perceptions of Helpfulness of Case Studies in Fall 2011

<table>
<thead>
<tr>
<th>Degree of Benefit</th>
<th>RU (n=79)</th>
<th>TU (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very beneficial</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>15.2%</td>
<td>30.4%</td>
</tr>
<tr>
<td>Beneficial</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>29.1%</td>
<td>39.1%</td>
</tr>
<tr>
<td>Somewhat beneficial</td>
<td>24</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>30.4%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Not very beneficial</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16.5%</td>
<td>8.7%</td>
</tr>
<tr>
<td>Not beneficial</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>7.5%</td>
<td>8.7%</td>
</tr>
<tr>
<td>No response</td>
<td>1</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>1.3%</td>
<td>n/a</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 4 illustrates students’ responses to how beneficial they believed the multimedia case studies were to their learning in spring of 2012. Of the 31 RU students participating in case studies, six students (19.4%) found the case studies “very helpful,” six students (19.4%) found the case studies “helpful,” and ten students (32.3%) found them “somewhat helpful.” Five RU students (16.1%) found the case studies “not very” helpful, and two students (6.5%) found them “not” helpful. Overall, 22 RU students (71.0%) rated the case studies from “somewhat” to “very beneficial.” At TU, three students (60.0%) rated the case studies as “very beneficial”, while one student (20.0%) rated them as “not” beneficial.

Table 4
Perceptions of Helpfulness of Case Studies in Spring 2012

<table>
<thead>
<tr>
<th>Degree of benefit</th>
<th>RU (n=31)</th>
<th>TU (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very beneficial</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>19.4%</td>
<td>60.0%</td>
</tr>
<tr>
<td>Beneficial</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>19.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Somewhat beneficial</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>32.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Not very beneficial</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>16.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Not beneficial</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>6.5%</td>
<td>20%</td>
</tr>
<tr>
<td>No response</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>6.5%</td>
<td>20%</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Discussion

The goal of this qualitative research has been to “describe, understand, and interpret” student perceptions of the effectiveness of multimedia case studies in introductory engineering courses at two universities (one research university and one teaching university). Based on the findings, the
following section seeks to highlight potential areas of strength and improvement that student participants identified in relation to how introductory engineering courses are designed and conducted.

Presage
The two student populations in Introduction to Engineering courses at RU and TU are typically traditional undergraduate students, yet they are very different. RU students tend to be freshmen and, for the most part, Caucasian; these students are primarily engineering majors. The TU courses have mostly African-American business or engineering majors who are sophomores, juniors, and seniors. At both universities, the majority of the students in these courses are male; however, TU has a larger female population enrolled in these courses than does RU, where courses averaged two or three females per course. Most students had little to no prior experience with engineering concepts, other than high school courses or summer internships. A few indicated that they had exposure to engineering concepts through having family members who were engineers or who worked in occupations that use engineering concepts.

Pedagogy
Several themes were identified in the data that related to pedagogy. These are discussed below.

Faculty Teaching and Learning. The faculty team consisted of the principal investigators, course instructors, lab instructors, and evaluators. Weekly teleconferences facilitated discussion among faculty team members about what pedagogical changes were needed and how they should be implemented to improve student learning. Lessons plans and evaluation procedures were planned as a team. One of the most important findings of this study was that interaction between the faculty members from different disciplines was helpful to everyone’s learning.

Teaching faculty were encouraged to draw on more novel ways to present concepts and vary the pedagogical approaches used in lectures and labs. Differences in resources available at the two universities meant that we had to think of a variety of ways to present instruction at both universities without students at one university having an advantage over students at the other university, because of better technology or access to other resources, such as lab materials. Evaluators were emboldened to think about different ways to assess progress. Together, we decided how the project would be implemented, listened to each other’s ideas and inputs, shared resources, and used feedback from students to improve the course each semester.

Regular feedback from students at the end of each semester enabled us to make pedagogical changes to the curriculum in these courses to better meet students’ learning needs. For example, their feedback on the use of multimedia case studies indicated that these cases were excellent tools for teaching them to consider various viewpoints and situations, gave them an appreciation for teamwork and creativity, and enabled them to share ideas and engage in critical thinking. Students felt that the multimedia case studies provided a real world application of the engineering concepts they were learning and taught them management principles, such as leadership and ethics, to extend their engineering foundations skills.

Early in the study, students gave feedback that helped us to improve how the cases were used, and the changes that were implemented made the use of multimedia case studies more effective.
For example, originally, students were assigned a multi-media case study to do, which included reading and video watching. Students complained that there was too much verbiage (one link was about 40 pages of text). Their feedback included that they wanted the cases to be used in a more student-focused, collaborative way; therefore, we changed the format of instruction to use the case studies as the basis for student discussions, and students were assigned to groups to prepare a presentation to the rest of the class on a certain aspect of the case. Improving communication skills was one focus for the use of cases; students suggested that they be allowed to present on different aspects of each case to avoid repetitious presentations. Students indicated that, while they enjoyed the case studies and found them to be helpful, having too many of them used in a semester course made the cases monotonous and boring. As a result, we reduced the number of cases used to two or three per semester to avoid students’ inattention.

Thinking Outside of the Box. In recent years, engineering instruction has focused on the use of lecture to relate engineering concepts16. Today’s students are more technologically oriented and may find lecture to be passé. Such was the case with the students in Introduction to Engineering courses at both universities. After each semester, via surveys and focus group discussions, we asked them about their preferred way to learn new concepts. Table 5 illustrates the preferences of students (helpful “teaching styles”) in Introduction to Engineering courses at the two universities for fall semester 2011 in relation to the most helpful ways to be taught engineering concepts.

Learner-centered Instruction. At both universities, students indicated an interest in hands-on activities, as they provide a means for students to work on teams to accomplish an engineering design task and to compete against each other, which keep them involved and interested. Case studies provided variety to students and gave them the opportunity to learn about decisions and, in some cases, mistakes that engineers made and their consequences. These activities enabled them to work on their team building skills and presentation skills as a group and as individuals. The case studies also provided students with a connection between engineering concepts and the real world in terms of helping them to see what engineers really do in their daily work. Once again, students expressed excitement about the competitive nature of the case study presentations. To build on this interest factor, instructors may wish to present cases that focus on current events and give students various options to investigate and defend, then have other students score the presentations, based on a rubric.

Table 5
Most Helpful Teaching Styles at both Universities, Fall 2011- Spring 2012

<table>
<thead>
<tr>
<th>Teaching style</th>
<th>Fall 2011</th>
<th></th>
<th>Spring 2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RU (N=79)</td>
<td>TU (N=23)</td>
<td>RU (N=87)</td>
<td>TU (N=23)</td>
</tr>
<tr>
<td>Group projects</td>
<td>39 (49.3%)</td>
<td>8 (34.8%)</td>
<td>10 (11.5%)</td>
<td>11 (47.8%)</td>
</tr>
<tr>
<td>PowerPoint</td>
<td>26 (32.9%)</td>
<td>13 (56.5%)</td>
<td>30 (34.5%)</td>
<td>8 (34.8%)</td>
</tr>
<tr>
<td>Lecture</td>
<td>18 (22.7%)</td>
<td>3 (13%)</td>
<td>35 (40.2%)</td>
<td>4 (17.4%)</td>
</tr>
<tr>
<td>Hands on</td>
<td>20 (25.3%)</td>
<td>1 (4.3%)</td>
<td>8 (9.2%)</td>
<td>0</td>
</tr>
<tr>
<td>Examples</td>
<td>4 (5%)</td>
<td>1 (4.3%)</td>
<td>5 (5.8%)</td>
<td>0</td>
</tr>
<tr>
<td>Visuals</td>
<td>2 (2.5%)</td>
<td>1 (4.3%)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Case studies</td>
<td>12 (15.2%)</td>
<td>5 (21.7%)</td>
<td>5 (5.8%)</td>
<td>0</td>
</tr>
</tbody>
</table>
Recommended Design Considerations for Introductory Engineering Courses

*Improving the Lecture Experience.* Lectures need to be more interactive than reading off of a slideshow presentation. Instructors should pause to interact with students, taking questions or feedback from them, and possibly including the working of interesting problems. Use of interesting examples (why certain engineering designs fail) and guest speakers from industry stand to improve the lecture experience and student learning.

*The Use of Hands-on Labs.* Students recommended that hands-on labs continue to be used extensively in the course, citing active engagement and relevance to their interests and needs as future engineers and business majors. The group work (students tended to like group work; see below) design of the hands-on labs aided in their positive feelings about the course. Students often commented on the lack of connection, however, between the lecture session and the lab session. Course designers should consider ways to include hands-on activities in introductory engineering courses in support of stated learning objectives. Further, creating alignment between lecture and lab may strengthen course efficacy and appeal.

*Questions of Relevance of Course Topics.* Course material was often seen as irrelevant to future work or redundant (as when students thought they had already learned the material). The implication of comments made in these areas would suggest the need for instructors to communicate relevance to students. If the concepts being taught were something students would likely see as familiar (e.g., ethics), it may become important that instructors take extra steps to explain to students why the concept matters in the context of engineering. Greater attention to creating connections between seemingly familiar subjects (e.g., ethics in general as taught in English classes or other contexts) and engineering (e.g., ethics in engineering and why it matters) may increase student perception of relevance. What may seem obvious to a course instructor (e.g., ethics in engineering is really important) may seem overstated and redundant to students. Therefore, it is the responsibility of instructors and course designers to ensure the relevance connection is present in the course.

*Use of Group Work.* Participants in both semesters at both universities overwhelmingly approved of the use of group work in the implementation of learning through multimedia case studies and hands-on lab experiences. While a few students admitted to a preference for working alone, the majority seemed to note the appropriateness of groups as it fostered improved critical thinking and design solutions when faced with challenging design problems and little time to solve them. Students appreciated the opportunities to lead groups and to benefit from other engineering and business perspectives group members might bring, and they noted its relevance to their future “real-world” work.

*Ambivalence towards Working with Robots.* Students at RU worked with robots, and their comments are nearly divided in half, where some favor working with robots and others do not. Students recommended more explicit instruction related to the robot software (LabView), and they found extensive software glitches to make the learning experience feel more like punishment than learning. Many students felt the number of robot labs (approximately nine per semester) was too high for an introductory engineering course. On the positive side, some students appreciated the challenge and felt satisfaction when robots responded appropriately after
hours of coding. While use of robots may be widespread in such courses, course designers should ask if their extensive use is necessary and appropriate to stated course objectives and adjust accordingly.

**Use of Multimedia Case Studies.** Students recognized the ability of the multimedia case study to bring real-world issues to life. In addition, several felt the case study provided a missing piece between the disconnected lecture sessions and lab sessions. Several students praised the use of case studies as tools for illustrating the daily lives of real engineers. Problems with the case studies tended to relate to how they were implemented: students said they could have done them at home; some students found the subsequent round table activity to be awkward, and for some students, their awareness of the historical outcome of the case made it difficult to argue for the “losing side” of a case. Students in a course where the instructor conveyed firm expectations on the final round table exercise seemed to find more satisfaction than those in the section where they felt they could “wing it.” Course designers of introductory engineering courses should carefully consider where students complete the case studies, whether this ought to occur in groups or with students as individuals, and how students can best show evidence of learning. Feedback from participants in this evaluation study suggested that use of the round table discussion as a follow-up to the multimedia case study is more effective when the instructor conveys clear expectations. Use of rubrics provided before the round table performance may aid in improved communication of clear expectations.

**Limitations of this Study.** The fall 2011 focus groups were conducted via teleconference. For the most part, the focus groups went smoothly, but occasional problems included echo and inability to hear and see clearly, which hindered communication. The researchers feel that the focus group communication may have been reduced (in terms of how much participants were willing to interact and in terms of overall engagement with the discussion) by this format. In addition, the issue of focus group recruitment arose wherein groups were either too large (up to 20), or group members did not show up. The incentive to attend the focus group varied by institution and even within the institution (notably at TU in spring 2012, where one group was given extra credit for attending, while the other was not). In the future, improved efforts to streamline recruitment across and within the universities may be beneficial.

**Bibliography**


